THE

Watch & Clockmakers'

HANDBOOK,

BY

F. J. BRITTEN.

FOURTH EDITION.

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For the past four or five years I have been continually urged to add to the little pamphlet issued under the title of "The Watch and Clockmakers' Handbook." The majority of my correspondents were country watchmakers and most of them indicated some particular subject on which information would be welcome. These expressions of opinion all pointed to the production of a book by some one practically acquainted with the various branches of the watch and clock trades, and I therefore felt considerable hesitation in attempting a task I could not hope to accomplish without more assistance than I had any right to expect. But help has been freely given and, however incomplete and badly put together this little work may be, the fact that it is in some measure a reflex of the experience of the most eminent men engaged in the horological arts leads me to hope it may be of value.

Northampton Square, London,

December, 1881.

NOTE.—By a misprint in a footnote at page 89, 12ozs. of standard silver is said to contain 11ozs. 10dwts. of pure silver. In other parts of the book it is correctly stated as 11ozs. 2dwts. The final word of the last foot note on page 81 should be pendulum instead of bob. I may add that in constructing a pendulum it will be sufficiently near to assume the centre of oscillation to be coincident with the middle of the bob.

WATCH & CLOCKMAKERS' HANDBOOK.

Signs and Abbreviations.

$=$ is the sign of Equality; thus, $A = 6$ means that A is equal to 6.

$+$ (plus) is the sign of Addition; thus, $6 + 4$ means 6 added to 4.

$-$ minus or less than; thus, $5 - 2$, which means 5 minus 2.

$\times$ signifies Multiplication; thus, 5×2 means 5 multiplied by 2. Multiplication is also indicated by writing the factors when they are not numerals one after the other; thus, $c\ d\ e$, which means c multiplied by d and the product thereof multiplied by e.

$\div$ stands for Division; thus, $12 \div 3$ means 12 divided by 3. Division is also indicated by writing the divisor under the dividend with a line between them; thus, $\frac{a}{b}$, which means that a is to be divided by b.

: :: : signifies Proportion; thus, $2 : 3 :: 4 : x$, which means as 2 is to 3 so is 4 to x, or to the answer which when unknown is usually indicated by x.

A small ^{2} placed at the upper right hand corner of a quantity indicates that the square or second power of the quantity is to be taken; thus, 3^2 means the square of 3, that is 3 multiplied by itself.

If the index figure is ³ instead of ² it indicates that the third power or cube of the quantity is to be taken; thus, 6^3 means the cube of 6 or $6 \times 6 \times 6$.

$\sqrt{}$ stands for root and if used as shown without a small figure attached represents the square root; thus $\sqrt{9}$ means the square root of 9.

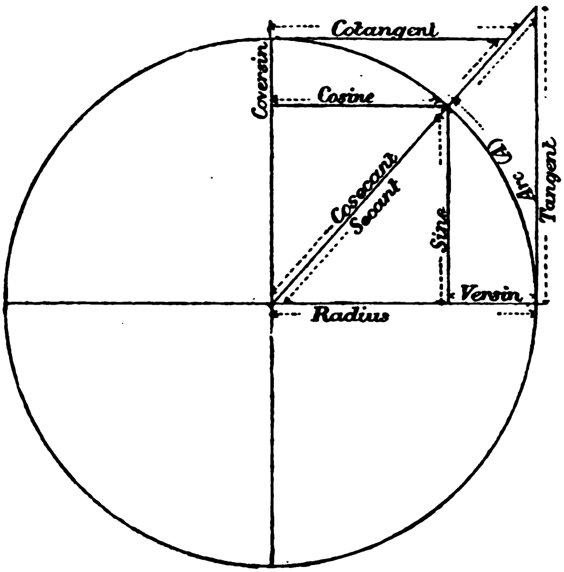
$\sqrt[3]{}$ represents the third or cube root.

———— When a bar is appended to quantities it indicates that the quantities are to be taken together; thus, $\sqrt{20 \times 12} + 6$, which means that 20 is to be first multiplied by twelve and the square root of the product is to be extracted and added to 6. If the bar were not there it would mean that the square root of 20 was to be extracted and this root multiplied by 12 and the product added to 6, Instead of a bar being used quantities which are to be taken together are sometimes enclosed in parenthesis ( ) or brackets [ ]

Min.	Minute of time $= \frac{1}{60}$th of an hour.
Sec.	Second of time $= \frac{1}{360}$th of an hour.
°	Degrees of Arc.
′	Minute of Arc $= \frac{1}{60}$th of a Degree.
″	Second of Arc $= \frac{1}{360}$th of a Degree.
Rad.	Radius = the semi diameter.
Tan.	Tangent.
Sin.	Sine.
Sec.	Secant.
Versin.	Versed sine.
Cotan.	Complement tangent.
Cosin.	Complement sine.
Cosec.	Complement secant.
Coversin.	Complement versed sine.
$\angle$	Angle.
∟	Right angle.
$\triangle$	Triangle.

Trigonometrical Definitions.

A Circle is divided into 360 degrees, and each quadrantal arc therefore contains 90. If a quadrantal arc is divided into two parts, as in the diagram, whatever number of the degrees is contained in the one part (A) the difference or complement of 90 is contained in the other part.



Taking the radius as 1, the value of the various functions of a given angle and of its complement may be thus expressed.

$\sqrt{(1-\text{Sin.}^2)}=\text{Cos}$	$\sqrt{(1-\text{Cosin}^2)}=\text{Sin.}$
Sin ÷ Tan = Cos	Cosin ÷ Cotan = Sin.
Sin × Cotan = Cosin	1 ÷ Cotan = Tan.
Sin ÷ Cos. = Tan.	1 ÷ Sin. = Cosec.
Cos. ÷ Sin = Cotan.	1 ÷ Cosine = Sec.
$\text{Sin}^2 + \text{Cos}^2 = \text{Rad}^2$	1 ÷ Cosecant = Sin.
$\text{Rad}^2 + \text{Tan}^2 = \text{Sec}^2$	1 ÷ Secant = Cosin
1 ÷ Tan. = Cotan.	Rad—Sin = Coversin

If the sine of the angle A in the diagram were produced till it touched the lower part of the circle it would then form a chord of double the angle ; therefore, Sin $\overline{\angle \div 2} \times 2 =$ Chord.

Table of Sines, Tangents, &c.

Deg.	Sine.	Cover.	Cosecnt.	Tangt.	Cotang.	Secant.	Vrsn.	Cosin.
0	·00	1·00000	Infinite.	·0	Infinite.	1·00000	·0	1·00000
1	·01745	·98254	57·2986	·01745	57·2899	1·00015	·0001	·99984
2	·03489	·96510	28·6537	·03492	28·6362	1·00060	·0006	·99939
3	·05233	·94766	19·1073	·05240	19·0811	1·00137	·0013	·99862
4	·06975	·93024	14·3355	·06992	14·3006	1·00244	·0024	·99756
5	·08715	·91284	11·4737	·08748	11·4300	1·00381	·0038	·99619
6	·10452	·89547	9·5667	·10510	9·5143	1·00550	·0054	·99452
7	·12186	·87813	8·2055	·12278	8·1443	1·00750	·0074	·99254
8	·13917	·86082	7·1852	·14054	7·1153	1·00982	·0097	·99026
9	·15643	·84356	6·3924	·15838	6·3137	1·01246	·0123	·98768
10	·17364	·82635	5·7587	·17632	5·6712	1·01542	·0151	·98480
11	·19080	·80919	5·2408	·19438	5·1445	1·01871	·0183	·98162
12	·20791	·79208	4·8097	·21255	4·7046	1·02234	·0218	·97814
13	·22495	·77504	4·4454	·23086	4·3314	1·02630	·0256	·97437
14	·24192	·75807	4·1335	·24932	4·0107	1·03061	·0297	·97029
15	·25881	·74118	3·8637	·26794	3·7320	1·03527	·0340	·96592
16	·27563	·72436	3·6279	·28674	3·4874	1·04029	·0387	·96126
17	·29237	·70762	3·4203	·30573	3·2708	1·04569	·0436	·95630
18	·30901	·69098	3·2360	·32491	3·0776	1·05146	·0489	·95105
19	·32556	·67443	3·0715	·34432	2·9042	1·05762	·0544	·94551
20	·34202	·65797	2·9238	·36397	2·7474	1·06417	·0603	·93969
21	·35836	·64163	2·7904	·38386	2·6050	1·07114	·0664	·93358
22	·37460	·62539	2·6694	·40402	2·4750	1·07853	·0728	·92718
23	·39073	·60926	2·5593	·42447	2·3558	1·08636	·0794	·92050
24	·40673	·59326	2·4585	·44522	2·2460	1·09463	·0864	·91354
25	·42261	·57738	2·3662	·46630	2·1445	1·10337	·0936	·90630
26	·43837	·56162	2·2811	·48773	2·0503	1·11260	·1012	·89879
27	·45399	·54600	2·2026	·50952	1·9626	1·12232	·1089	·89100
28	·46947	·53052	2·1300	·53170	1·8807	1·13257	·1170	·88294
29	·48480	·51519	2·0626	·55430	1·8040	1·14335	·1253	·87461
30	·50000	·50000	2·0000	·57735	1·7320	1·15470	·1339	·86602
31	·51503	·48496	1·9416	·60086	1·6642	1·16663	·1428	·85716
32	·52991	·47008	1·8870	·62486	1·6003	1·17917	·1519	·84804
33	·54463	·45536	1·8360	·64940	1·5398	1·19236	·1613	·83867
34	·55919	·44080	1·7882	·67450	1·4825	1·20621	·1709	·82903
35	·57357	·42642	1·7434	·70020	1·4281	1·22077	·1808	·81915
36	·58778	·41221	1·7013	·72654	1·3763	1·23606	·1909	·80901
37	·60181	·39818	1·6616	·75355	1·3270	1·25213	·2013	·79863
38	·61566	·38433	1·6242	·78128	1·2799	1·26901	·2119	·78801
39	·62932	·37067	1·5890	·80978	1·2348	1·28675	·2228	·77714
40	·64278	·35721	1·5557	·83909	1·1917	1·30540	·2339	·76604
41	·65605	·34394	1·5242	·86928	1·1503	1·32501	·2452	·75470
42	·66913	·33086	1·4944	·90040	1·1106	1·34563	·2568	·74314
43	·68199	·31800	1·4662	·93251	1·0723	1·36732	·2686	·73135
44	·69465	·30534	1·4395	·96568	1·0355	1·39016	·2806	·71933
45	·70710	·29289	1·4142	1·00000	1·0000	1·41421	·2928	·70710
	Cosin.	Versin.	Secant.	Cotang.	Tangt.	Cosenct.	Covsn.	Sine.

Decimal Fractions.

As I have used Decimal Fractions throughout this book a few explanatory remarks thereon may not be unacceptable to the younger readers.

Ciphers to the right hand of decimals cause no difference in their value. ·5 or ·50 or ·500 is of the same value. ·5 represents $\frac{5}{10}$, ·50 represents $\frac{50}{100}$, and ·500 represents $\frac{500}{1000}$, and each of them is equal to $\frac{1}{2}$. But every cipher placed on the left hand of decimals diminishes their value tenfold; thus, ·3,·03 and ·003 represent respectively 3-tenths three-hundredths and three-thousandths.

In the addition of decimals or whole numbers and decimals the lines must be arranged so that the decimal points are all directly under one another. The addition will then be proceeded with as in whole numbers.

In the subtraction of decimals or decimals and whole numbers arrange the lines as in addition.

In the multiplication of decimals or decimals and whole numbers arrange the figures as with whole numbers and point off from right hand of the product as many decimals as there are in the multiplier and multiplicand together. If there are not enough figures in the product to do this add the requisite number of ciphers to the LEFT hand of the product.

In the division of decimals or whole numbers and decimals the quotient must contain as many decimals as the dividend has more than the divisor. For instance, if there are two decimal figures in the divisor and three in the dividend cut off one figure at the right hand of the quotient as a decimal. If there are not enough figures in the quotient to carry out this rule add the requisite number of ciphers to the LEFT hand of the quotient.

To reduce a vulgar fraction to a decimal add a cipher or ciphers to the numerator and divide by the denominator, the quotient will be the decimal required.

EXAMPLE.—Reduce $\frac{7}{8}$ to a decimal.

```
8) 7·000 (·875, the decimal required.
   64
   —
    60
    56
    —
    40
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When figures in the quotient repeat continually, they are called a repetend, and the last figure should be marked with a dash to distinguish it from a terminal decimal. Sometimes two, three or more figures will repeat in regular order; such figures are termed a circulate and may be indicated in the same manner as a repetend.

Standards of Time.

Solar Time.—Solar time is marked by the diurnal revolution of the earth with regard to the sun, so that the instant the sun is seen at its greatest height above the horizon it is true mid-day, which sometimes takes place 16m. 18s. sooner, and at others 14m. 28s. later than twelve o'clock mean time.

The diurnal revolution of the earth on its axis might naturally be supposed to bring each place to the meridian at regular intervals; this would be nearly the case if the earth had no other movement than its rotation on its axis, as a day would then be measured by a revolution of the equator, but it advances at the same time in its orbit, and as the meridians are not perpendicular to the ecliptic the days are not of equal duration; this may be easily perceived by placing a mark at every 15 degrees of the equator and ecliptic on a terrestrial globe, as by turning it to the westward the marks on the ecliptic, from Aries to Cancer, will come to the brazen meridian sooner than the corresponding ones on the equator, those from Cancer to Libra later, from Libra to Capricorn sooner, and from Capricorn to Aries later; the marks on the ecliptic and equator only coming to the meridian together at Aries, Cancer, Libra and Capricorn; thus, true and mean time would agree on the days in which the sun enters these signs, which is on the 20th March, 21st June, 23rd September, and 21st December, were it not that the earth moves with greater rapidity in December, when it is nearest the sun, than it does in July, when it is at its greatest distance from it. The regularity of the earth's motion is also farther disturbed by the attraction of the Moon, Venus and Jupiter. At present true and mean agree about the 25th December, 15th April, 14th June, and 31st August, but these days change, because the two points in the earth's orbit in which it is at its greatest and least distance from the Sun, move forward 12'' of a degree every year, and the equinoctial and solstitial points, 50'' of a degree backward.

Sun dials mark *true* time; while clocks measure *equal*, or *mean* time; if, therefore, a time-keeper, perfectly regular in its motion, were set to *true* or *solar* time, it would be found to agree with it only on four days in the year; to compare it with the sun on any intermediate day it would be necessary to add or substract, as shown by the Equation Table on page 9, which indicates the difference between solar and mean time at different periods in the year.

Equation Table computed to Minutes of Time.

Clock faster than the Sun.		*Min.*	*Clock slower than the Sun.*		*Min.*	*Clock faster than the Sun.*		*Min.*	*Clock slower than the Sun.*		*Min.*
December	26	1	April	17	1	June	17	1	September	2	1
,,	28	2	,,	22	2	,,	22	2	,,	6	2
,,	30	3	,,	28	3	,,	26	3	,,	8	3
January	1	4	May	6	4	July	1	4	,,	11	4
,,	3	5	,,	23	3	,,	7	5	,,	14	5
,,	5	6	June	1	2	,,	14	6	,,	17	6
,,	7	7	,,	7	1	August	8	5	,,	20	7
,,	9	8	,,	14	0	,,	14	4	,,	23	8
,,	12	9				,,	19	3	,,	26	9
,,	15	10				,,	23	2	,,	29	10
,,	18	11				,,	27	1	October	2	11
,,	21	12				,,	31	0	,,	5	12
,,	25	13							,,	9	13
,,	30	14							,,	12	14
February	24	13							,,	17	15
March	1	12							,,	23	16
,,	6	11							November	14	15
,,	10	10							,,	19	14
,,	14	9							,,	23	13
,,	17	8							,,	26	12
,,	21	7							,,	29	11
,,	24	6							December	2	10
,,	27	5							,,	4	9
,,	30	4							,,	7	8
April	3	3							,,	9	7
,,	6	2							,,	11	6
,,	10	1							,,	13	5
,,	15	0							,,	15	4
									,,	18	3
									,,	20	2
									,,	22	1
									,,	25	0

To Trace a Meridian.—The following are Ferguson's concise instructions for drawing a meridian line. "Make four or five concentric circles, a quarter of an inch from one another, on a flat board about a foot in breadth, and let the outmost circle be but little less than the board will contain. Fix a pin perpendicularly in the centre and of such a length that its whole shadow may fall within the innermost circle for at least four hours in the middle of the day. The pin ought to be about the eighth part of an inch thick, with a round blunt point. The board being set exactly level, in a place where the sun shines, suppose from eight in the morning till four in the afternoon, about which hours the end of the shadow should fall without all the circles; watch the times in the afternoon, when the extremity of the shortening shadow just touches the several circles, and there make marks. Then, in the afternoon of the same day, watch the lengthening shadow, and where its end touches the several circles in going over them make marks also. Lastly, with a pair of compasses, find exactly the middle points between the two marks on any circles, and draw a straight line from the centre to that point, which line will be covered at noon by the shadow of a small upright wire, which should be put in place of the pin. The reason for drawing several circles is, that in case one part of the day should prove clear, and the other part somewhat cloudy, if you miss the time when the point of the shadow should touch one circle, you may perhaps catch it in touching another. The best time for drawing a meridian line in this manner is about the middle of summer, because the sun changes his declination slowest and his altitude fastest in the longest days."

If the casement of a window, on which the sun shines at noon, be quite upright, you may draw a line along the edge of its shadow on the floor, when the shadow of the pin is exactly on the meridian line of the board: and as the motion of the shadow of the casement will be much more sensible on the floor, than that of the shadow of a pin on the board, you may know to a few seconds when it touches the meridian line on the floor, and so regulate your clock for the day of the observation by that line, and the Equation table before mentioned.

You will then have mean solar time correct for the particular place. But if it is desired that the clock should show the mean time of Greenwich or some other standard meridian a further correction for longitude must be made. I have given at pages 14, 15 and 16, a table showing the difference between mean time at Greenwich, and other places.

Cycle of the Sun.—A cycle of the sun is a period of 28 years, after which the days of the week again fall on the same days of the month as during the first year of the former cycle.

The cycle of the sun has no relation to the sun's course, but was invented for the purpose of finding the Dominical letter which points out the days of the month on which the Sundays fall during each year of the cycle.

Cycles of the sun date nine years before the Christian era. If it be required to know the year of the cycle in 1882, nine added will make 1891, which, divided by 28, gives the quotient 68, the number of cycles that have passed, and the remainder 15 will be the year of the cycle answering to 1882.

Sidereal Time is measured by the diurnal revolution of the earth, which turns on its axis in 23 hours 56 min. 4·1 sec.; a star will, therefore, always appear at the meridian about 3m. 56s. sooner than it did on the preceding day. This uniformity is caused from the fixed stars being at such immense distances, and the orbit of the earth so small in comparison, that the earth, with regard to them, appears to have no other motion than its diurnal rotation, consequently a complete revolution of the terrestrial equator brings the same stars to the meridian at perfectly regular intervals.

	STARS GAIN.		
Days	*hours*	*min.*	*sec.*
1	0	3	56
2	0	7	52
3	0	11	48
4	0	15	44
5	0	19	39
6	0	23	35
7	0	27	31
8	0	31	27
9	0	35	23
10	0	39	19
11	0	43	15
12	0	47	11
13	0	51	7
14	0	55	3
15	0	58	58
16	1	2	54
17	1	6	50
18	1	10	46
19	1	14	42
20	1	18	38

The motion of the earth, with regard to the fixed stars being uniform, time-pieces can be regulated to mean time by the stars with greater facility than by the sun. Choose a window having a southern aspect, from which the steeple of a church, a chimney, or any other fixed point may be seen. To the side of the window attach a piece of card-board having a small hole in it in such a manner that by looking through the hole towards the edge of the elevated object, some of the fixed stars may be seen; the progress of one of these must be watched, and the instant it vanishes behind the fixed point a signal must be made to a person observing the clock, who must then remark the exact time at which the star disappeared, and on the following night the same star will vanish behind the same object 3m. 56s. sooner. If a clock mark ten when the observation is made, when the star vanishes the following night it should indicate 3m. 56s. less than ten.

If several cloudy nights have rendered it impossible to compare the clock with the star, it will then be necessary to multiply 3m. 56s. by the number of days that have elapsed since the observation, and the product deducted from the hour the clock then indicates gives the time the clock ought to show.

The same star can only be observed during a few weeks, for as it gains nearly one hour in a fortnight it will, in a short time, come to the meridian in broad day-light and become invisible; to continue the observation another star must be selected.

In making the observation care must be taken that a planet is not observed instead of a star; Mars, Jupiter and Saturn are those most likely to occasion this error, more especially Saturn, which from being the most distant of the three resembles a star of the first magnitude.

The planets may, however, be easily distinguished, for, being comparatively near the earth, they appear larger than the stars; their light also is steady because reflected, while the fixed stars scintillate and have a twinkling light. A sure means of distinguishing between them is to watch a star attentively for a few nights, if it change its place with regard to the other stars it is a planet.

Duration of a Year.—The Earth performs its revolution round the Sun in 365 days, 5 hours, 48 min., 49·7 secs. No account was taken of the odd hours till the year, B.C. 45, when the error in the computation of the year had become very considerable. The surplus, 5 hours, 48 min., 49·7 sec., was then taken as 6 hours, making one day in four years; this day was therefore added to every fourth year. There still remained the apparently trifling difference of 11 min. 11 sec. between the computed and the real year; this, however, produced an error of about seven days in 900 years. In 1582, Pope Gregory XII. struck out ten days, which represented the accumulated error, from the calendar, and it was decided that three leap years should be omitted every 400 years; thus, as 1,600 was leap year the years 1,700, 1,800 and 1,900 are not, but 2,000 will be leap year. This rectification was not adopted in England till 1752, when eleven days were omitted from the calendar. As our year still exceeds the true year, although by an extremely small fraction, another leap year in addition to those should be omitted once in 4,000 years.

The Golden Number.—Meton, an Athenian astronomer, B.C. 432, discovered that after a period of 19 years the new and full moons returned on the same days of the month as they had done before; this period is called the cycle of the moon.

The Greeks thought so highly of this calculation that they had it written in letters of gold, hence the name golden number; and at the council of Nice, A.D. 325, it was determined that Meton's cycle should be used to regulate the movable feasts of the church.

Our Saviour was born in the second year of the lunar cycle. To find the year of the cycle, add one to the present year, divide this by 19, and the remainder will give the year of the cycle. 1882 divided by 19 leaves a remainder of 2, which is therefore the golden number for 1882.

The Epact serves to find the moon's age by showing the number of days which must be added to each lunar year, in order to complete a solar year.

A lunar month is composed of 29 days, 12 hours, 44 min., 3 sec., or rather more than 29·5 days; twelve lunar months are, therefore, nearly 11 days short of the solar year—thus, the new moons in one year will fall 11 days earlier than they did on the preceding year, so that were it new moon on January 1st, it would be nearly eleven days old on the 1st of January of the ensuing year, and 22 days on the third year; on the fourth year it would be 33; but 30 days are taken off as an intercalary month (the moon having made a revolution in that time) and the three remaining would be the Epact; the Epact thus continues to vary, until, at the expiration of 19 years, the new moons again return in the same order as before.

If the solar year were exactly 11 days longer than 12 lunar months, it would only be necessary to multiply the golden number by 11, divide the product by 30, and the remainder would be the Epact; but as the difference is not quite 11 days, one must be taken from the golden number, the remainder multiplied by 11, and the product, if less than 30, shows the Epact; but if more it must be divided by 30, and the remainder is the Epact for that year. The golden number for 1882 being 2, 1 multiplied by 11 = 11, which is the Epact for 1882.

To find the moon's age upon any particular day, add the number placed against the month in the following table to the Epact and day of the month, the product, if under 30, will be the moon's age; should it exceed this number, divide by 30, and the remainder will show it:—

January	2	April	2	July	5	October	8
February	3	May	3	August	7	November	10
March	1	June	4	September	7	December	10

From the irregularity of the number of days in the calendar months and other causes, it is difficult to make an exact calculation, but the error resulting from this rule does not exceed one day.

The Number of Direction.—The Council of Nice decided, A.D. 325, that Easter Day is always the first Sunday after the full moon, which happens upon or next after the 21st of March. Easter Day, therefore, cannot take place earlier than the 22nd of March, or later than the 25th of April. The Number of Direction is that day of the thirty-five on which Easter Sunday falls.

The Roman Indiction.—The Roman Indiction was a period of 15 years appointed A.D. 312, by the Emperor Constantine for the payment of certain taxes.

The Julian Period.—The Julian Period of 7980 years is the product obtained by multiplying together 28, 19 and 15, which numbers represent the cycles of the Sun, the Moon and the Roman Indiction. The beginning of the Julian Period is reckoned from 709 before the Creation of the World, so that its completion will occur A.D. 3267, until which time there cannot be two years having the same numbers for the three cycles.

Difference between Greenwich Mean Time and Local Time at the Principal Places throughout the World.

The word fast after any place indicates that the local time is fast of Gr eenwich time and the word slow that it is slow of Greenwich time.

NOTE.—Four minutes in time = 1 degree of longitude.

ENGLAND AND WALES.

Place		M.	S.
LONDON—			
Aldgate Church ...	slow	0	17
Bank of England ...	slow	0	20
Battersea Church ...	slow	0	42
Berkeley Square ...	slow	0	35
Blackfriars Bridge ...	slow	0	24
British Museum ...	slow	0	30
Fulham Church ...	slow	0	50
Hampstead Church...	slow	0	43
Highgate Church ...	slow	0	35
Kensington Palace ...	slow	0	45
Muswell Hill ...	slow	0	29
Sloane Square ...	slow	0	38
St. Paul's	slow	0	23
Streatham Church ...	slow	0	31
Westminster Abbey	slow	0	30
Abingdon	slow	5	4
Alderney	slow	8	48
Alnwick	slow	6	52
Andover	slow	5	52
Arundel...	slow	2	20
Appleby	slow	9	52
Ashford, Kent... ...	fast	3	32
Ashton-under-Lyne ...	slow	8	24
Aylesbury	slow	3	20
Banbury	slow	5	12
Bangor	slow	16	32
Barnstaple	slow	16	20
Bath	slow	9	28
Bedford...	slow	1	52
Berwick-on-Tweed ...	slow	8	0
Beverley	slow	1	44
Bideford	slow	16	56
Birkenhead	slow	12	4
Birmingham	slow	7	36
Blackburn	slow	9	52
Boston	—	—	
Bodmin...	slow	19	0
Bradford, Yorkshire ...	slow	7	0
Brecknock	slow	14	0
Brentford	slow	1	20
Bridgnorth	slow	9	40
Bridgwater	slow	12	0
Brighton	slow	0	36
Bristol	slow	10	24
Buckingham	slow	3	56
Burnley...	slow	8	56
Burton-on-Trent ...	slow	6	28
Bury	slow	9	4
Bury St. Edmunds ...	fast	2	48
Cambridge	fast	0	23
Canterbury	fast	4	50
Cardiff	slow	13	4
Cardigan	slow	17	20
Carlisle	slow	11	44
Carmarthen	slow	17	56
Carnarvon	slow	17	0
Chatham	fast	2	20
Chelmsford	fast	0	30
Cheltenham	slow	8	20
Chester	slow	11	36
Chichester	slow	3	20
Chippenham	slow	8	0
Christchurch	slow	7	0
Cockermouth	slow	13	30
Colchester	fast	3	28
Coventry	slow	6	0
Darlington	slow	6	8
Deal	fast	5	36
Derby	slow	5	52
Devizes	slow	7	52
Devonport	slow	16	48
Dewsbury	slow	6	28
Douglas, Isle of Man ...	slow	17	56
Dorchester	slow	9	48
Dover	fast	5	16
Droitwich	slow	8	52
Dudley	slow	8	16
Durham...	slow	7	36
Eastbourne	fast	1	0
Epsom	slow	1	4
Exeter	slow	14	12
Falmouth	slow	20	8
Faversham	slow	3	36
Flint	slow	12	1
Folkstone	fast	4	36
Gateshead	slow	6	24
Gloucester	slow	9	0
Grantham	slow	2	40
Gravesend	fast	1	50
Grimsby	slow	0	16
Guernsey	slow	10	12
Guildford	slow	2	0
Halifax	slow	7	32
Harrowgate	slow	6	8

		M.	S.
Hartlepool	slow	4	40
Harwich	fast	5	8
Hastings	fast	2	24
Hereford	slow	11	0
Hertford	slow	0	20
Holyhead	slow	18	36
Horsham	slow	1	40
Huddersfield	slow	7	20
Hull	slow	1	20
Huntingdon	slow	0	50
Ilfracombe	slow	16	28
Isle of Wight, Newport	slow	15	5
Ipswich	fast	4	40
Jersey	slow	8	28
Kendall	slow	7	0
Kew Observatory	slow	1	14
Kidderminster	slow	4	45
King's Lynn	fast	1	50
Lancaster	slow	11	5
Leamington	slow	6	20
Leeds	slow	6	4
Leominster	slow	11	0
Leicester	slow	4	33
Lewes	fast	0	5
Lichfield	slow	7	10
Lincoln	slow	2	4
Liskeard	slow	17	50
Liverpool	slow	12	0
Llanelly	slow	16	40
Louth	—		—
Macclesfield	slow	8	40
Malvern, Great	slow	9	16
Maidstone	fast	2	20
Manchester	slow	8	52
Margate	fast	5	55
Merthyr Tydfil	slow	13	30
Middlesborough	slow	4	56
Monmouth	slow	11	56
Montgomery	slow	13	0
Morpeth	slow	6	50
Newcastle	slow	6	24
Northampton	slow	3	30
Nottingham	slow	4	30
Norwich	fast	4	48
Oakham	slow	2	50
Oldham	slow	8	25
Pembroke	slow	19	48
Penzance	slow	22	20
Peterborough	slow	0	50
Plymouth	slow	16	36
Poole	slow	7	50
Portsmouth	slow	16	36
Preston	slow	10	50
Ramsgate	slow	5	55
Reading	slow	3	55
Reigate	slow	0	48
Rochester	fast	2	59

		M.	S.
Runcorn	slow	11	0
Salford	slow	9	4
Salisbury	slow	7	8
Scarborough	slow	1	25
Sheffield	slow	5	50
Sheerness	fast	2	59
Shields, North	slow	5	48
Shields, South	slow	5	35
Shoreham	slow	1	8
Shrewsbury	slow	10	56
Southampton	slow	5	36
Southport	slow	12	0
Stafford	slow	8	30
Staleybridge	slow	8	5
Stamford	slow	1	55
Stockport	slow	8	45
Stockton-on-Tees	slow	5	20
Stroud	slow	8	50
Sunderland	slow	5	28
Swansea	slow	15	40
Taunton	slow	12	25
Tavistock	slow	16	35
Teignmouth	slow	13	46
Tiverton	slow	14	10
Torquay	slow	13	5
Truro	slow	20	0
Tunbridge Wells	fast	1	4
Wakefield	slow	5	45
Walsall	slow	7	55
Wareham	slow	8	30
Warrington	slow	10	20
Warwick	slow	6	5
Wednesbury	slow	8	4
Wenlock	slow	10	0
Westbury	slow	8	30
Weston-super-Mare	slow	11	48
Weymouth	slow	9	45
Whitby	slow	2	28
Whitehaven	slow	14	24
Wigan	slow	10	30
Winchester	slow	5	20
Windsor	slow	2	30
Wisbeach	fast	0	50
Wolverhampton	slow	8	25
Woodstock	slow	5	30
Worcester	slow	8	50
Worthing	slow	1	30
Yarmouth	fast	7	0
York	slow	7	16
SCOTLAND.			
Aberdeen	slow	8	20
Abroath	slow	10	8
Ayr	slow	18	36
Banff	slow	10	0
Dumbarton	slow	18	16
Dumfries	slow	14	24
Dundee	slow	11	52

		M.	S.
Edinburgh	slow	12	50
Elgin	slow	13	28
Forfar	slow	11	20
Glasgow	slow	17	3
Greenock	slow	19	1
Inverness	slow	16	54
Kilmarnock	slow	18	0
Kirkaldy	slow	12	36
Kirkwall	slow	11	48
Leith	slow	12	36
Montrose	slow	9	52
Paisley	slow	17	40
Perth	slow	13	30
Stirling	slow	15	50
Wick	slow	12	36

IRELAND.

Note.—Dublin time is kept throughout Ireland.

		M.	S.
Dublin	slow	24	48
Armagh	slow	26	40
Bandon	slow	34	48
Belfast	slow	23	40
Cork	slow	33	56
Downpatrick	slow	22	52
Drogheda	slow	25	20
Dundalk	slow	25	0
Enniskillen	slow	30	40
Galway	slow	36	12
Kilkenny	slow	29	10
Kingstown	slow	24	32
Limerick	slow	34	30
Lisburn	slow	24	5
Londonderry	slow	29	20
Queenstown	slow	32	52
Sligo	slow	33	52
Waterford	slow	28	36
Wexford	slow	25	56
Wicklow	slow	24	8
Youghal	slow	31	24

OTHER COUNTRIES.

		H.	M.	S.
Adelaide	fast	9	14	40
Alexandria	fast	1	56	20
Algiers	fast	0	12	20
Amsterdam	fast	0	19	32
Athens	fast	1	34	32
Auckland	fast	11	39	4
Barbadoes, Bridgetown	slow	3	59	0
Berlin	fast	0	53	36
Bombay	fast	4	51	30
Brisbane	fast	10	10	40
Brussels	fast	0	17	26
Buenos Ayres	slow	3	53	35
Calcutta	fast	5	53	56
Canton	fast	7	32	56
Cape Town	fast	1	12	4
Cairo	fast	2	5	0
Calais	fast	0	7	25
Chicago	slow	5	50	38
Christiana	fast	0	43	0
Colombo	fast	6	31	0
Constantinople	fast	1	56	0
Copenhagen	fast	0	50	16
Geneva	fast	0	24	28
Gibralter	fast	0	21	24
Hamburgh	fast	0	39	50
Havre	fast	0	36	0
Jamaica, Kingston	slow	5	7	12
Jeddo	fast	9	18	52
Jerusalem	fast	2	35	0
Lima	slow	5	8	22
Lisbon	slow	0	36	37
Madeira	slow	1	7	36
Madras	fast	5	20	56
Madrid	slow	0	13	40
Malta	fast	0	58	0
Melbourne	fast	9	39	50
Mexico	slow	6	45	40
Milan	fast	0	36	40
Montreal	slow	4	54	0
Morocco	slow	0	26	0
Moscow	fast	2	29	52
Munich	fast	0	46	12
Natal	fast	2	0	2
New York	slow	4	56	0
Palermo	fast	0	53	32
Paris	fast	0	9	21
Pekin	fast	7	45	52
Philadelphia	slow	5	40	0
Quebec	slow	4	48	0
Rangoon	fast	6	25	20
Rome	fast	0	49	53
St. Helena	slow	0	23	4
St. John's, New Brunswick	slow	4	24	24
St. John's, Newfoundland	slow	3	30	52
St. Petersburg	fast	2	14	4
St. Thomas	slow	4	20	3
San Francisco	slow	8	10	0
Santa Cruz	slow	1	4	56
Shanghai	fast	8	3	20
Stockholm	fast	1	12	12
Sydney	fast	10	4	44
Téheran	fast	3	25	22
Tripoli	fast	0	52	44
Tunis	fast	0	40	44
Venice	fast	0	49	20
Vienna	fast	1	5	[illegible]
Warsaw	fast	1	28	
Wellington, N.Z.	fast	11	39	

Wheels and Pinions.

In the construction of watches and clocks it is necessary to transmit motion from one arbor to another so that the arbor which is driven revolves more quickly than the one which drives it. If it were practicable to use rollers with smooth edges for transmitting such motion the diameter of the rollers would be inversely proportionable to the number of revolutions made by their arbors in a given time. For instance, the distance apart of two arbors from centre to centre measures 3.7 inches, and it is desired that for every time the arbor from which the power is taken revolves the other shall revolve eight times. The distance between the arbors is divided into nine equal parts, of which eight are taken for the radius of the driver which revolves only once, and one part for the radius of the follower as it is called, which revolves eight times. Although it is not practicable to drive with smooth rollers, which would slip unless pressed so tightly together as to cause excessive friction, the circles representing the rollers are the basis on which the wheel and pinion are constructed. They are called the pitch circles. The acting part of the teeth of the driver is beyond its pitch circle and the acting part of the teeth of the follower within its pitch circle. In most of the toothed wheels with which watchmakers are concerned the driver is the wheel and the follower the pinion. The shape for the acting part of the wheel teeth is an epicycloid, a curve generated by rolling one circle on another.

Fig. 2.—Generating Circle tracing Epicycloid for Wheel Tooth by rolling on the Pitch Circle.

In Fig. 2 is shown a portion of a circle representing the pitch diameter of the wheel and on it a smaller circle rolling in the direction of the arrow. If these two are made of brass or any thin material and laid on a sheet of paper, a pencil fixed to the circumference of the small roller will trace a curve as shown. This curve is the acting part of the wheel tooth.

The acting part of the pinion leaves must be produced by the same sized roller as was used for the points of the wheel teeth but in a different manner. The pinion flanks should be hypocycloidal in form. A hypocycloid is obtained by rolling one circle within another instead of upon it. The most convenient size for the generating roller for both wheel and pinion is half the pitch diameter of the pinion. In Fig. 3 is a circle representing the pitch circle of the pinion with another circle half its size rolling within it, and in this case the point described by the pencil would be a straight radial line, which is a suitable form for the pinion leaves.

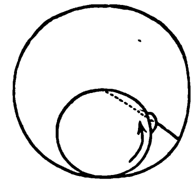


FIG. 3.

Fig. 3.—Generating Circle tracing Hypocycloid Pinion flanks by rolling inside the Pitch Circle.

Teeth formed in this way will transmit the motion uniformly at the same speed as though the pitch circles rolled on each other without teeth and will also meet another important requirement. The action between the teeth will take place almost wholly after the line of centres—that is if the pinion have not less than ten leaves. The difference between engaging and disengaging friction is very great, especially if the surfaces in contact are not quite smooth. Wheels which have any considerable portion of their action between the teeth as they are engaging or before the line of centres not only absorb considerable power thereby but wear out rapidly.

The pitch circle of the wheel is spaced out so that the teeth and the spaces are equal. To allow of necessary freedom the teeth or leaves of the pinion are less in width than the spaces. The distance between the centre of one leaf and the centre of the next may be divided into ·6 for space and ·4 for leaf.*

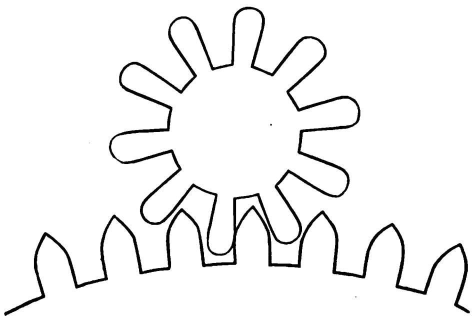


Fig. 4.—Portion of Wheel with Pinion having Circularly Rounded Leaves.

* The "pitch" of wheels and pinions is the portion of the circumference of the pitch circle between the centre of one tooth and the centre of the next.

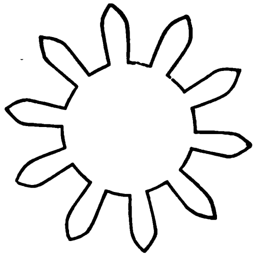


Fig. 5.—Pinion with Epicycloidal Addenda.

The pinion leaves are finished with a semicircular piece projecting beyond the pitch circle, as seen in Fig. 4. They would work without if properly pitched, but would not be safe as the depth became shallow from the wearing of the holes. Some prefer a Gothic shaped projection like Fig. 5, which is of epicycloidal form, the same as the wheel teeth. This is a very suitable form if the pinions are low numbered, for although with it the action takes place more before the line of centres a safer depth is ensured. The teeth of the wheel are extended within the pitch line to allow of clearance for the addendum of the pinion. The root or part of the wheel took below the pitch line is generally radial. The corners at the bottom of the tooth may be rounded for strength but these round corners must not be so full as to engage the points of the pinion leaves. The action should be confined as nearly as possible to the epicycloid on the wheel and the hypocycloid on the pinion. In watches the roots of all the wheels and pinions are left square except the roots of the barrel or great wheel teeth and the roots of the centre pinion leaves, which should always be rounded for strength. There is then less danger of the teeth stripping if the main spring breaks.

If the pinion is to be used as the driver and the wheel as the follower, as is the case in the motion work of watches and clocks, the points of the pinion teeth must be epicycloidal and the roots of the wheel teeth hypocloidal struck with the same generating circle. For the convenience of using wheels and pinions indiscriminately as drivers and followers engineers generally use a generating circle whose diameter = the pitch × 2·22 for the points and roots of all wheels and pinions of the same pitch. The tip of the addendum is removed in both wheels and pinions.

If more than two wheels gear together the acting parts of all should be struck from the same sized generating circle. The number of teeth in a wheel bears exactly the same proportion to the number of teeth in a pinion with which it gears, as the diameter of the pitch circles of the wheel and pinion bear to each other. If the pinion whose pitch circle is ·8 of an inch in diameter has 10 teeth then the wheel with a pitch circle of 6·4 inches in diameter will have 80 teeth because ·8 is contained 8 times in 6·4 and 10 × 8 = 80. But the outside or full diameter of a wheel or pinion is not proportional to the pitch diameter. The addendum or portion of the tooth beyond the acting part bears reference rather to the size of the generating circle and to the width of the teeth than to the diameter of the wheel or pinion.

The tables on page 22, prepared by Mr. A. Lange, give the amount to be added to the pitch diameters in order to obtain the full diameter of wheels and pinions, in which the teeth and spaces of the wheel are of equal width and the pinion leaves ·4 of the pitch. Mr. Lange has taken the height of the addendum of the wheel to be equal to the width of the tooth, which is sufficiently accurate for all practical purposes. When a slide guage is used for measuring pinions with an odd number of leaves the true diameter is not obtained because the points of the teeth are not opposite. To meet this a separate column is given showing the proper allowance to be made.

These tables will be useful in drawing off the caliper of a watch or clock and in many other instances when it is desired to find the full diameter from the pitch diameter or to find the pitch diameter when the full diameter is given.

Example.—The full diameter is required of a pinion having 10 teeth whose pitch diameter is ·8. In table 2 opposite 10 we find 1·126 as the full diameter of a pinion whose pitch diameter is 1. Then ·8 × 1·126 = ·9008 the full diameter required.

If the full diameter is known and the pitch diameter is required the full diameter is to be *divided* by the number in the table.

Example.—The full diameter of a pinion with 10 leaves being ·9008 what is its pitch diameter? Then ·9008 ÷ 1·126 = ·8, which is the pitch diameter as given in the preceding example.

In drawing off the caliper of watches and clocks it often occurs that the numbers of a wheel and pinion are known and also the distance apart of their centres; their diameters are then required. Then the pitch diameter of the wheel and pinion together = twice the distance of centres given. This whole distance is then to be divided into two portions. If we take the sum of the wheel and pinion teeth to represent the whole length then the length of the portion representing the diameter of the wheel will be in proportion to the number of teeth contained in the wheel and the remaining portion will represent the pitch diameter of the pinion.

Example.—A wheel of 80 and a pinion of 10 are to be planted 3·6 inches apart—centre to centre. Required their respective diameter. Then 3·6 × 2 = 7·2, and 90 : 7·2 : : 80 : 6·4, which is the pitch diameter of the wheel. And 7·2 — 6·4 gives ·8 for the pitch diameter of the pinion.

Lantern pinions work very smoothly as followers though they are unsuitable as drivers. The space occupied by the shrouds precludes their use in watches, but in the going parts of clocks they answer well.

For the convenience of ready calculation it may be assumed that the addendum of the wheel teeth increases the size of the wheel by three teeth, For instance, the pitch diameter of a wheel of 80 teeth is 2 inches. Then its pitch diameter would bear the same proportion to its full diameter as 80 does to 83; or 80 : 2 : : 83 : 2·07, which is the full diameter.

In the same way it may be taken that the circular addendum increases the size of the pinion by 1·25 teeth and the epicycloidal addendum by 1·98, or nearly 2 teeth. This is, of course, supposing the width of the pinion leaf to be ·4 of the pitch.

If the pinion is to be used as the driver it must have the epicycloidal addendum to ensure proper action. I believe an opinion prevails among some watchmakers that the circularly rounded pinions may be used as driver if they are sectored large and that they are so used for motion work, but such a practice is altogether wrong.

In the motion work of keylcss watches the followers are used as drivers when the hands are being set and a good form of tooth for motion work generally may be obtained by using for roots and points of both wheels and pinions a generating circle of a diameter equal to twice the pitch. This gives a short tooth which will run smoothly when of full width. The form of gearing suitable for the train permits of too much shake for motion work.

TABLE 1.—FOR THE FULL DIAMETER OF WHEELS FROM 10 TO 100 TEETH; THE PITCH DIAMETER BEING = 1.

Number of Teeth	*True Diameter*	*Number of Teeth*	*True Diameter*	*Number of Teeth.*	*True Diameter.*	*Number of Teeth*	*True Diameter.*
10	1·315	33	1·096	56	1·056	79	1·0400
11	1·286	34	1·093	57	1·055	80	1·0395
12	1·260	35	1·090	58	1·054	81	1·0390
13	1·243	36	1·087	59	1·053	82	1·0385
14	1·225	37	1·085	60	1·052	83	1·0380
15	1·210	38	1·083	61	1·051	84	1·0375
16	1·197	39	1·081	62	1·0508	85	1·0371
17	1·185	40	1·079	63	1·050	86	1·0366
18	1·175	41	1·077	64	1·0493	87	1·0363
19	1·166	42	1·075	65	1·0485	88	1·0360
20	1·157	43	1·073	66	1·0477	89	1·0355
21	1·150	44	1·072	67	1·0470	90	1·0350
22	1·143	45	1·070	68	1·0462	91	1·0346
23	1·137	46	1·068	69	1·0456	92	1·0343
24	1·131	47	1·067	70	1·0450	93	1·0339
25	1·126	48	1·066	71	1·0445	94	1·0335
26	1·121	49	1·064	72	1·0438	95	1·0332
27	1·117	50	1·063	73	1·0431	96	1·0330
28	1·113	51	1·062	74	1·0426	97	1·0325
29	1·109	52	1·061	75	1·0420	98	1·0321
30	1·105	53	1·060	76	1·0415	99	1·0318
31	1·102	54	1·058	77	1·0409	100	1·0315
32	1·099	55	1·057	78	1·0404		

TABLE 2.—FOR PINIONS WITH CIRCULARLY ROUNDED LEAVES LIKE FIG. 4: THE PITCH DIAMETER BEING = 1.

Number of Pinion.	*Full or True Diameter.*	*Diameter of Bottom.*	*Thickness of Teeth.*	*Diameter for Uneven Teeth.*
6	1·209	0·402	0·209	
7	1·180	0·477	0·180	1·121
8	1·157	0·533	0·157	
9	1·140	0·572	0·140	1·106
10	1·126	0·611	0·126	
11	1·114	0·640	0·114	1·092
12	1·105	0·666	0·105	
13	1·097	0·684	0·097	1·081
14	1·090	0·701	0·090	
15	1·084	0·717	0·084	1·072
16	1·078	0·729	0·078	
17	1·074	0·741	0·074	1·063
18	1·070	0·751	0·070	
19	1·066	0·760	0·066	1·059
20	1·063	0·768	0·063	

TABLE 3.—FOR PINIONS WITH EPICYCLOIDAL ADDENDUM LIKE FIG. 5; THE PITCH DIAMETER BEING = 1.

Number of Pinion Leaves.	*True Diameter.*	*Diameter of Bottom.*	*Thickness of Leaves.*	*Diameter for Uneven Numbered Leaves.*
6	1·314	0·402	0·209	
7	1·270	0·477	0·180	1·206
8	1·235	0·533	0·157	
9	1·209	0·572	0·140	1·173
10	1·188	0·611	0·126	
11	1·171	0·640	0·114	1·148
12	1·157	0·666	0·105	
13	1·145	0·684	0·097	1·128
14	1·135	0·701	0·090	
15	1·126	0·717	0·084	1·113
16	1·118	0·729	0·078	
17	1·111	0·741	0·074	1·101
18	1·105	0·751	0·070	
19	1·099	0·760	0·066	1·093
20	1·094	0·768	0·063	

The Sector or Proportional Gauge.

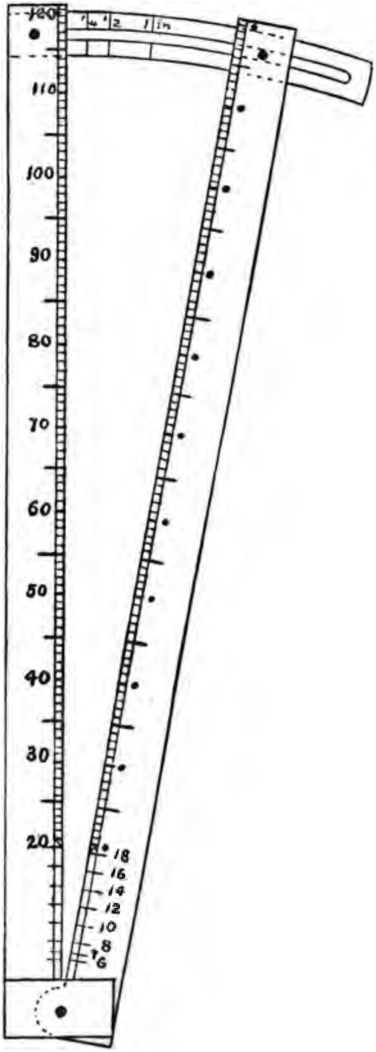


Fig. 6.—The Sector or Proportional Guage.

'his invaluable and simple tool, which is shown in Fig. 6 aprs to be but rarely understood. The measuring of wheels and pinions by its means is but one of its many uses. The sector is really a proportional measuring gauge, suited for nearly all requirements of the watch and clockmaker.

Construction of the Sector.—The length of the sector is quite unimportant; it may be made of any size considered to be most convenient for handling. It consists of two brass limbs carefully jointed at one end so that the centre of the joint pin is in a line with the inner faces of the limbs. The inner edges should be perfectly true and parallel. By means of a brass arc and thumb-nut at the other end of the sector the limbs may be fixed in any desired position. The following are the dimensions of one of Jump's sectors :—

Length of limbs	16·5	inches
Do. do. from centre of motion ...	16·125	„
Width of each limb...	·8	„
Length of slot in arc	4·625	„
Width of slot	0·15	„
Thickness of limbs	0·1	„
Thickness of cover plates for joint... ...	0·18	„
Thickness of arc	0·05	„
Diameter of steel joint pin	0·1	„

In order to get the joint pin in a line with the faces of the limbs, a knuckle projects beyond the face of the right hand or moving limb, and a corresponding piece is cut out of the left hand or fixed limb. The cover plates for joints are strongly rivetted to the fixed limb.

To Divide the Sector.—The first mark (120) having been made somewhere near the top of the limbs, the distance between this mark and the centre of the joint pin is divided into six equal parts, marked 100, 80, 60, 40, and 20, the last or zero is, of course, the centre of the joint pin. The part from zero to 20 is devoted to the sizing of pinions, and the division of it will be referred to presently. Each of the other five divisions is divided into 20 equal parts as shown, at every fifth part a longer stroke is made and at every tenth part a number, so that these points may be easily recognized. The numbers are placed on the fixed limb and may be repeated on the moveable limb, or represented by a dot as shown.

The limbs should be opened so that the distance between them at the 100 mark is exactly one inch, and a line drawn across the arc coincident with the inner face of the movable limb. This line is marked 1 inch. The limbs are then closed till the space between them at the 100 mark is half an inch, and another line drawn across the arc in a similar way. The process is repeated at ·25 and ·125 of an inch.

If larger measurements than an inch are to be taken other datum lines can be drawn across the arc as may be desired.

For the sizing of pinions the edges of the limbs up to the figure 20 are chamfered away to give a thinner edge. The 6 mark instead of being $\frac{6}{20}$ of the whole distance between zero and 20 is placed $\frac{1}{30}$ higher, then from 6 to 8 is $\frac{2}{20}$ of the whole distance between zero and 20; 8 to 10, 10 to 12, 14 to 16, and 16 to 18 the same. The 7 mark is not midway between 6 and 8, but is placed $\frac{1}{20}$th of the distance between 6 and 8, nearer to 6. These are Jump's proportions, and they are pretty generally adopted. Some few consider the pinions should be larger, and therefore place the 6 mark higher than Jump. After all, the proper size of pinions depends upon the shape of the addendum. See article on Wheels and Pinions at page 17.

The Sector would certainly be much handier, especially for taking very small measurements, and for obtaining the pitch diameters of pinions when the centres and numbers only of a wheel and pinion are known, if the limbs were divided equally all through. There does not seem to be any difficulty in doing so if the marks referring to the sizing of pinions were taken right across the limbs and the figures relating thereto placed on the outer edge.

Use of the Sector.—If the movable limb of the sector is fixed at the one inch line on the arc, the distance between the limbs at the 100 mark measures one inch; at the 90 mark, ·9 inch; at the 80 mark, ·8 inch, and so on downwards till the 20 mark is reached, when the distance is ·2 inch. But it may be desired to measure something smaller than ·2 inch. Then the limbs are set at the half-inch on one of the other datum lines on the arc. If at the half-inch line the 90 mark would show ·45; the 80 mark, ·4; the 70 mark, ·35; the 60 mark, ·3, and so on. If the limbs are set at the ·25 line the 90 mark would show ·225; the 80 mark, ·2; the 70 mark, ·175; the 60 mark, ·15; the 50 mark, ·125, and so on. In each case the distance between one mark and the next is $\frac{1}{10}$ of the distance between one of the figures and the next, so that whatever datum is selected it is divided decimally. For instance, it may be convenient to take the measurements in millimetres; it is only necessary to set the limbs so that the distance between them at the 100 mark is, say 10 millimetres, and draw a line across the arc so that the limbs may be fixed at the same spot on another occasion.

In the forgoing examples the sector takes the place of the ordinary slide gauge or other measuring tool. It is especially useful as a proportional measurer. For instance, in the article on

Main Springs it is stated that taking the diameter of the inside of a barrel as 100, then with the main spring in, the unoccupied part of the barrel should show a diameter of 74, and the barrel arbor 33. Set the limbs so that the 100 mark corresponds to the inner diameter of the barrel, and the 74 mark shows the size of the spring and the 33 mark the size of the arbor.

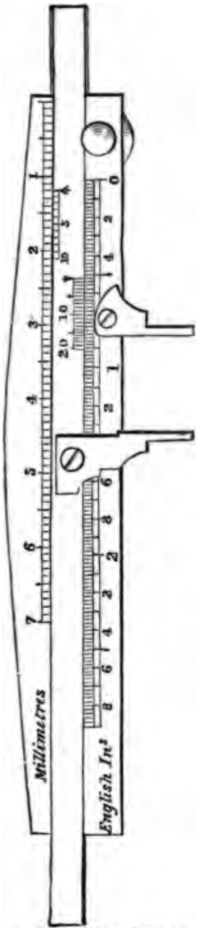
For Sizing Wheels and Pinions.—Suppose a pinion of 8 is required for a wheel of 75 teeth; the wheel is placed between the limbs at the 75 mark and the proper size for the pinion is then the distance between the limbs at the 8 mark. Of course, if the pinion is in hand and the size of wheel is required the operation is reversed; the pinion is placed between the limbs at the 8 mark and the distance between the limbs at the 75 mark gives the size of the wheel.

The numbers of a wheel and pinion and their distance apart from centre to centre being given their respective pitch diameters may be obtained by means of the sector, provided it is equally divided all through, as recommended in a preceding paragraph. Suppose a wheel of 60 and a pinion of 8 are to be planted ·75 apart; open the sector so that at 68 (which is the sum of the wheel and pinion teeth) the width between the limbs is double the distance of centres —that is 1·5 inch. Then the width between the limbs at 60 will represent the pitch diameter of the wheel and at 8 the pitch diameter of the pinion. The full diameters may be obtained by means of the tables given at page 22. Or the full diameters may be obtained at one operation instead of the pitch diameters by adding 3 to the number of the wheel teeth and 1·25 to the pinion, if it have circular, or 2 if epicycloidal addenda. Say it is a circularly rounded pinion, the sector would then be opened so that at 72·25 the width was 1·5 inch, and the width at 63 would represent the full diameter of the wheel and the width at 9.25 the full diameter of the pinion.

The Vernier Slide Gauge.

This is the instrument in most general use among watchmakers for exact measurement. Its construction may be gathered from the annexed engraving (Fig. 7), which originally appeared in a useful little work on watchmaking by the late Charles Frodsham. To his son, Mr. H. M. Frodsham, I am indebted for the use of this block. The gauge there shown consists of a brass stock to which one of the tempered steel chops is screwed. A brass slide which carries a corresponding steel chop works freely in a dovetailed grove in the stock, the upper surface of the slide being level with the upper surface of the stock. A set screw at one end serves to tighten the dovetail and so fix the gauge, when it is desired to do so.

Fig. 7.



The stock is divided into inches, as denoted by the large figures at the outer edge, and the inches into tenths, the even tenths being marked by figures. Each tenth is again sub-divided into five equal parts, representing a fiftieth or ·02 of an inch. The Vernier is engraved on the slide. A length equal to nineteen-fiftieths of an inch is divided into twenty equal parts; each part is therefore a twentieth of nineteen-fiftieths or ·019 of an inch. Then, as the divisions on the stock are each ·02 of an inch while those of the Vernier are only ·019, it follows that their difference is ·001, or one-thousandth of an inch.

When the chops of the instrument are closed the zero points of the stock and the Vernier should exactly coincide. Then, when the chops are opened the distance between them will be indicated by the position of the zero point of the Vernier with relation to the scale on the stock, plus as many thousandths of an inch as there are divisions of the Vernier from zero before one coincides with a division on the stock. For instance, if the reading showed 5-tenths, 1 division of another tenth and 4 divisions of the Vernier the measurement would be—

$$·5 + ·02 + ·004 = ·524 \text{ of an inch.}$$

The scale at the back of the stock is divided into millimetres, the Vernier being 9 millimetres divided into 10 equal parts.

The Main Spring.

In order that the spring, when in the barrel, may undergo no injurious contraction, the barrel arbor should be one-third the diameter of the inside of the barrel; and when a suitable spring and arbor are in the barrel, there should be as much unoccupied space as is equal to the bulk of the spring. Then, if we suppose the inside diameter of the barrel to be divided into 100 equal parts, the spring will occupy, when nearest the circumference of the barrel, 26 of those parts (13 on each side); when wound close round the arbor, 41 parts; or, together with the arbor, 74 parts. These proportions may be readily measured with the Sector. (See article on the Sector at page 24.

In 8-day marine chronometers, taking the inner diameter of the barrel as 100, the arbor is generally made = 43, and then arbor and main spring wound should measure 77·4, and the coil of main spring when unwound 22·6, that is 11·3 on each side of the barrel.

Whatever the size of the arbor, IF THE OUTER DIAMETER OF THE SPRING WHEN IT IS WOUND IS THE SAME AS ITS INNER DIAMETER WHEN UNWOUND IT WILL BE RIGHT, and the difference between the number of coils when the spring is wound and when it is unwound will be the number of turns the barrel will make. In a great many instances too much spring is crowded into the barrel.

It may be required to find the proper thickness of the coiled ring of mainspring in other cases when the diameter of the arbor bears a different proportion to the size of the barrel.

Let B = inner diameter of the barrel.

„ A = diameter of arbor.

„ T = thickness of the ring of main spring when lying close to the rim of the barrel.

$$\text{Then } T = \frac{B - \sqrt{\left(\frac{B^2 + A^2}{2}\right)}}{2}$$

In order to get a given number of turns to find the number of coils there should be in the barrel when the main spring is unwound :—

Let M = the mean diameter of spring when unwound.

„ m = the mean diameter of spring when wound.

„ P = the proportion between the mean diameter of spring when unwound and its mean diameter when tightly coiled about the arbor.

„ t = the given number of turns.

„ C = the number of coils when the spring is unwound.

Then $P = M \div m$.

And $C = (P \times t) + 1{\cdot}5$

This gives an extra coil and a half on account of the ends of the spring not coming into action and will be found to be an ample allowance.

Example.—The diameter of a barrel being ·7 and the diameter of arbor ·233 it is required to get 6·5 turns. The diameter of the circle, which represents the inner diameter of spring when unwound and the outer diameter of it when wound, is ·52. The mean diameter of the unwound spring is ·61, and the mean diameter of it when wound is ·376.

Then $\cdot 61 \div \cdot 376 = 1{\cdot}62$. And $\overline{1{\cdot}62 \times 6{\cdot}5} + 1{\cdot}5 = 12{\cdot}03$, or say 12 coils.

Twelve coils when the spring is unwound is a suitable number for a barrel. As we see from the above example, it allows two turns for setting up and half a turn to spare.

For a fusee watch five turns and a quarter, giving three-quarters of a turn for setting up and half a turn to spare, would be sufficient for the most extreme case. Taking the preceding proportions we have $\overline{1{\cdot}62 \times 5{\cdot}25} + 1{\cdot}5 = 10$, which is the number of coils required for 5·25 turns. Generally but three and a half turns are required for use and unless an unusual length of the end of the spring is left soft less than three-quarters of a turn will suffice for setting up.

The ordinary custom of packing 13 or 14 turns into the barrel, filling it unnecessarily and leaving room for but 4.5 or 5 turns of action and little or nothing to set up, involves the use of the weak end of the spring only. An equal adjustment with greater power and freer action may be obtained with fewer coils as shown by the above examples.

If the vibration of a watch is too small it may often be sufficiently increased by breaking off one or two excessive coils of main spring.

To find the thickness of main spring necessary divide the thickness of the coiled ring of main spring when unwound by the number of coils.

Taking the thickness of ring and number of coils, as in the last example, we have—

·09 ÷ 10 = ·009 the thickness required.

Practically the thickness would be a little less, for the coils do not lie absolutely close together,

Hooking the Main Spring.—The attachment of the outer end of the main spring to the barrel is usually made either rigid by means of a square hook rivetted to the main spring or free to adjust itself

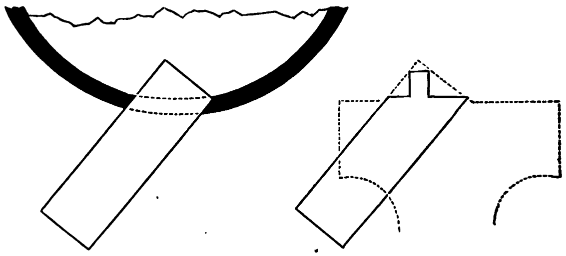


Fig. 8. *Fig. 9.*

by being hooked to a stud fixed in the barrel. A ready way of making the square hook is to fit a piece of rectangular steel to the hole in the barrel as shown at Fig. 8, first seeing that the hole in the barrel is not at a less angle than about 45°, or the hook will be apt to draw out when in use. When the steel is properly fitted mark on it with a fine point the curve of the inside and outside of the barrel, as shown by dotted lines in the figure, leaving enough of the steel inside the barrel to form the pivot. Then catch the steel in the vice at the same or a slightly less angle than it occupied in the barrel and form the pivot as close to the slope on which the strain comes as possible. Fig. 9 shows clearly what is meant, the jaw of the vice is there indicated by dotted lines. The object of placing the steel in the vice at a slighly less angle than it occupied in the barrel is so that when the hook is in action the strain shall be taken at the ROOT of the slope. Some watchmakers use a cutter for finishing the pivot and shoulder of the hook. It is formed of a piece of round steel, up the middle of which a hole is drilled of a size to just admit the nose of the pivot. At the end of the piece of steel around the hole serrations are filed. A few turns of this tool quickly finishes the pivot and shoulder. The pivot hole in the spring may now be made. If the spring is softened sufficiently to enable it to be drilled it will be right. The spring should not be tapered but just rounded at the end, and bent to the circle of the inside of the barrel. In large hooks the pivot should be annealed to a red or the rivet may crack. The hook may be removed for shortening the spring or applying another spring if care is taken to anneal the hook to a red before lifting the rivet. The rivet may be lifted after the spring is broken away by inserting the nippers under it. It may then be worked to a straight pivot with the pliers. Just before rivetting it again anneal it to a red.

The drawback to making the hook in the way just described is that the pivot cannot be got quite close to the slope on which the strain is taken. Mr. Bickley has favoured me with the following detailed instructions for hooking in the spring in the best manner, wherein the pivot is formed close to the root of the slope. Having selected a suitable spring, which to ensure freedom in the barrel must lie well under the groove of barrel cover, temper the end, taking care not to soften it too much or too far up the spring. Drill the pivot hole (supporting the spring against a piece of brass while doing so) pretty near to the hard part of the spring, and at a point corresponding in height to the centre of the barrel hole. If the pivot hole is made too much into the soft it will cause the spring to buckle or bend in rivetting the hook. Proceed to make the hook by turning or filing the pivot on a piece of narrow flat steel (fig. 10). The pivot must be straight, or very nearly so, and fit the spring hole tightly; the shoulder must be clean and square and lie close up to the spring. File the sides of the steel, keeping them parallel and with the pivot in the centre, until the end of the steel on either side of the pivot will pass freely through the barrel hole. Now make the back slope of the hook (fig. 11) at an angle of about 45°; hold the steel in the vice while doing so and continue the slope as in fig. 11 up to the pivot, taking care not to nick the latter at the root. Reverse the steel in the vice and file the front slope at the same angle as the back (fig. 12), shortening the base of the hook in the direction of the dotted line until it is right length. This will be determined by placing the back slope of the hook on the outer slope of the barrel hole, and trying it carefully and frequently until

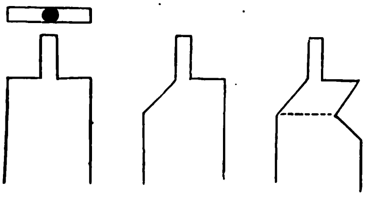


Fig. 10. *Fig. 11.* *Fig. 12.*

the front slope will pass through. The hook thus formed should pass freely through the hole, fitting it closely at the sides and ends, for more than the height eventually required. The pivot is now to be shortened to about twice the thickness of the spring, and rivetted slightly, the inner side of the hole having previously been chamfered to receive the rivet, which must project as little as possible above the spring. The hook is now to be cut off the steel as indicated by the dotted line in fig. 12, and filed to right height. To ascertain the right height pass the hook through the hole in the reverse direction to that above mentioned, *i.e.*, with the *front* slope of the hook towards the *outer* slope of the hole, and lower it until its height barely equals the thickness of the barrel rim. Polish the hook and before winding in see that the spring is perfectly flat and that its circular form is not disturbed at the hook. If properly made the hook will slip freely into the hole, and the outer coil of the spring will lie close to the inner circumference of the barrel. The outside of the barrel should never be filed, neither should the hook be tampered with after it is rivetted on the spring. If these directions are carefully followed but little practice will be needed to ensure good fits and to make the operation of hooking the main spring a simple one indeed.

The advantage generally claimed for the hook rivetted to the spring over the eye attached to a stud in the barrel is that the former being a rigid attachment keeps the coils of the spring equally diffused when under tension instead of allowing the turns to go over in a mass to the point of least resistance. But the spring must not be left perfectly hard at the rivet or it will break, and in many instances it is found that when the spring is wound it is bent at the rivet, forming an elbow. The advantage of the rigid attachment is then lost and the spring goes over at once to the point of least resistance. Sometimes the end of the spring beyond the hook is thinned and also filed to a point, but the chance of the spring breaking across the rivet is thereby much increased without serving any good purpose. This weakening of the projecting end appears to have been done at first to enable the watchmaker to tuck the end of the spring easily into the barrel when the spring is wound up on the spring tool; but the same convenience may be obtained when the end is left as strong as possible by bending it to the shape of the inside of the barrel. It will then slip in without trouble. If a main spring with a hook attachment keeps its shape without bending into an elbow at the rivet it will invariably be found upon examination that the barrel has been so full of spring that the angle of inflection when the spring is wound is very small. The spring is consequently but little strained at the hook. But this excess of spring is clearly not economy of room or power and does not permit of any better adjustment.

Fig. 13 shows the fixed stud in the barrel. The head of the stud should be in diameter about one-third of the width of the

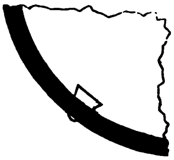


Fig. 13.

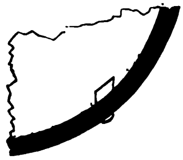


Fig. 14.

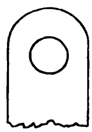


Fig. 15.

spring, made as thin as possible so as to project but little beyond the first coil of the spring. After the stud is screwed home it should be rivetted on the outside. The eye should be made close to the end of the spring, which should be rounded as shown in Fig. 15. It will then allow an amount of play on the detaining stud that will preclude all chance of breaking no matter to what angle the spring is drawn. The spring may also be wound up quite tight as often as may be without any bend or kink in the attachment. It may, therefore, be assumed that the eye is the best attachment, at all events for the going barrel in which the spring is required to be set up as much as possible in order to strengthen the lower coils and get a good adjustment. Instead of a stud screwed straight into the barrel as shown in Fig. 13 a straight pin is often screwed into the barrel at an angle of aout 45°, like Fig. 14. Where this is done it should be screwed in from the inside of the barrel, the end being finished to proper length and angle before the pin is removed from the screw plate. These pins are often left too long. A little more than the thickness of the first coil of spring is sufficient. More length besides taking up room in the barrel generally causes the barrel to bulge in the event of the spring breaking. Where the barrel is thin, care should be taken to have the thread of the screw sufficiently fine.

The advocates of the hook in the spring asserts that a better adjustment is obtained with a rigid attachment than with a yielding one, but I am told that the eye was used in preference for marine chronometers by the late John Poole, and most chronometer makers of the present day find there is no difference in the adjustment and also adopt the same kind of attachment.

The Lever Escapement.

(Invented by Thomas Mudge about 1770).

Although inferior for timekeeping to the Chronometer, the Lever Escapement when made with ordinary care is so certain in its action that it is generally preferred for pocket watches. Its weak point is the necessity of applying oil to the pallets. However close the rate of the watch at first, the thickening of the oil in the course of a few months will inevitably affect its going.

Action and Proportion of the Escapement.—Fig. 16 shows the most usual form of the lever escapement, in which the pallets "scape" over three teeth of the wheel. A tooth of the escape wheel is at rest upon the locking face of the entering left-hand pallet. The impulse pin has just entered the notch of the lever and is about to unlock the pallet. The action of the escapement is as follows:—The balance, which is attached to the same staff as the roller, is travelling in the direction indicated by the arrow which is around the roller, with sufficient energy to cause the impulse pin to move the lever and pallets far enough to release the wheel tooth from the locking face and allow it to enter on the impulse face of the pallet. Directly it is at liberty the escape wheel, actuated by the main-spring of the watch, moves round the same way as the arrow and pushes the pallet out of its path. By the time the wheel tooth has got to the end of the impulse face of the pallet its motion is arrested by the exit or right-hand pallet, the locking face of which has been brought into position to receive another tooth of the wheel. When the pallet was pushed aside by the wheel tooth it carried with it the lever which in its turn communicated a sufficient blow to the impulse pin to send the balance with renewed energy on its vibration. So that the impulse pin has the double office of unlocking the pallets by giving a blow on one side of the notch of the lever and of immediately receiving a blow from the opposite side of the notch. The balance proceeds on its excursion, winding up as it goes the balance spring, until its energy is expended. After it is brought to a state of rest its motion is reversed by the uncoiling of the balance spring, the impulse pin again enters the notch of the lever, but from the opposite direction, and the operation already described is repeated. The object of the safety pin is to prevent the pallets leaving the escape wheel except when the impulse pin is in the notch of the lever. The banking pins keep the motion of the lever within the desired limits. They should be placed as shown where any blow from the impulse pin on to the outside of

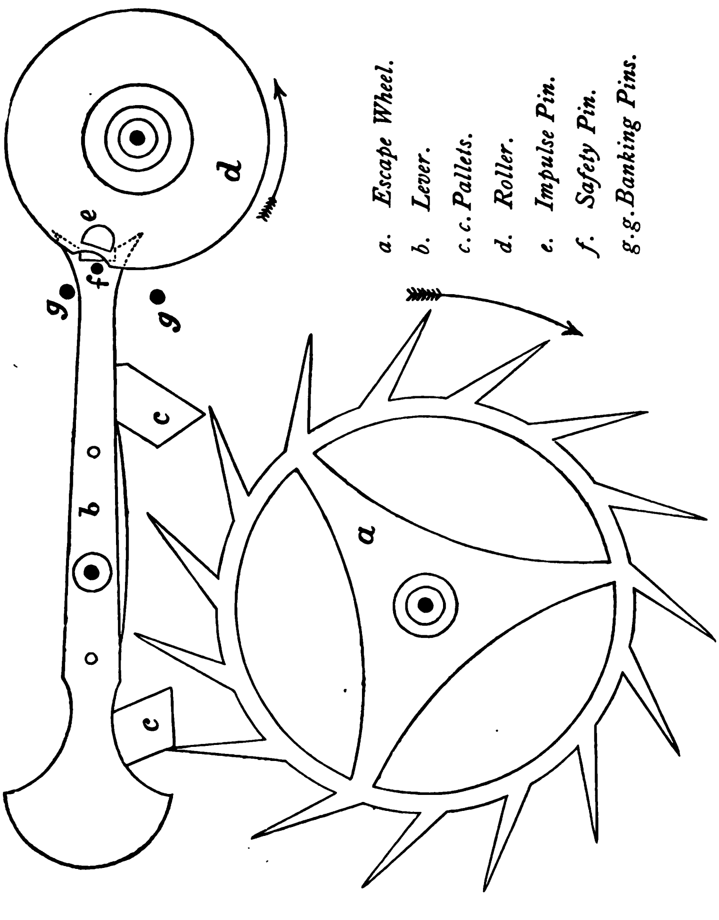


Fig. 16.

Lever Escapement.

the lever is received direct. They are sometimes placed at the tail of the lever but in that position the banking pins receive the blow through the balance pivots, which are liable to be broken in consequence.

The escape wheel has fifteen teeth and the distance between the pallets, from centre to centre, is equal to 60° of the circumference of the wheel. The pallets are planted as close as possible to the wheel, so that the teeth of the wheel in passing just clear the belly of the pallets.* The width of the pallets is made as nearly as possible half the distance between one tooth of the escape wheel and the next. As the teeth of the wheel must be of an appreciable thickness and the various pivots must have shake it is not found practicable to get the pallets of greater width than 10° of the circumference of the wheel instead of 12°, which would be half the distance between one tooth and the next. This difference between the theoretical and actual width of the pallet is called the drop. The lever is pinned to the pallets and has the same centre of motion. The distance between the centre of the lever and the centre of the roller is not absolute. The distance generally adopted is a chord of 96° of a circle representing the path of the tips of the escape wheel teeth, that is, the distance from the tip of one tooth to the tip of the fifth succeeding tooth. The proportion, as it is called, of the lever and roller is generally from 3 to 1 to $3\frac{1}{2}$ to 1. In the former case the length of the lever (measured from the centre of pallet staff to centre of impulse pin) is three times the distance of the centre of the impulse pin from the centre of the roller, and in the latter case $3\frac{1}{2}$ times. The portion of the lever to the left of the pallet staff hole acts as a counterpoise.

In this form of the lever escapement the pallets have about 10° of motion. Of this amount 2° are used for locking, and the remaining 8° for impulse. The amount of locking is to some extent dependent on the size of the escapement. With a large escapement less than $1\frac{1}{2}$° would suffice, while a small one would require rather more than 2°. The quality of the work, too, is an element in deciding the amount of locking. The lighter the locking the better, but it must receive every tooth of the wheel safely, and where all the parts are made with care the escapement can be made with a very light locking. 10° pallets with a lever and roller

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* When the tooth is pressing on the locking the line of pressure should pass through the centre of the pallet staff. But as the locking faces of the two pallets are not equidistant from the centre of motion a tangent drawn from the locking corner of one pallet would be wrong for the other, and as a matter of fact if a diagram is made it will be found that even when the pallets are planted as close as possible they are hardly as close as they should be for the right-hand pallet. To plant as close as possible is therefore a very good rule and is the one adopted by the best pallet makers.

3 to 1 give a balance arc of 30°—that is to say, the balance in its vibration is freed from the escapement except during 30° when the impulse pin is in contact with the lever.

When from setting the hands of a watch back, or from a sudden jerk, there is a tendency for the pallets to unlock, the safety pin butts against the edge of the roller. It will be observed that when the impulse pin unlocks the pallets the safety pin is allowed to pass the roller by means of the crescent which is cut out of the roller opposite the impulse pin. The teeth of the escape wheel make a considerable angle with a radial line (24°) so that their tips only touch the locking faces of the pallets. The locking faces of the pallets instead of being curves struck from the centre of motion of the pallets, as would be otherwise the case, are cut back at an angle so as to interlock with the wheel teeth.* This is done so that the safety pin shall not drag on the edge of the roller but be drawn back till the lever touches the banking pin. When the operation of setting the hands back is finished, or the other cause of disturbance removed, the pressure of the wheel tooth on the locking face of the pallet draws the pallet into the wheel as far as the banking pin will allow. The amount of this "run" should not be more than sufficient to give proper clearance between the safety pin and the roller, for the more the run the greater is the resistance to unlocking. This rule is sometimes sadly transgressed and occasionally the locking is found to be, from excessive run, almost equal in extent to the impulse. It will generally be found that in these cases the escapement is so badly proportioned that the extra run has had to be given to secure a sound safety action. In common watches the safety action is a frequent source of trouble. The more the path of the safety pin intersects the edge of the roller the sounder is the safety action, and if the intersection is small the safety pin is likely to jamb against the edge of the roller or even to pass it altogether. With an ordinary single roller escapement a sound safety action cannot be obtained with a less balance arc than 30°. Even with a balance arc of 30° the roller must be kept small in the following way to ensure the soundness of the safety action. The hole for the impulse pin must not be left round. After it is drilled a punch of the same shape as the impulse pin—that is, with one-third of its diameter flattened off—should be inserted and the edge of the roller, where the crescent is to be formed, beaten in. By this means the roller can be turned down small enough to get a sufficient intersection for the safety pin.

It is useful in estimating the balance arc of a watch if it has a three armed balance to remember that 30° is one-fourth of the distance between two arms.

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* The locking face forms an angle of 6° or 8° with a tangent to a circle representing the path of the locking corner.

A round impulse pin, although it is sometimes used in common watches, gives a bad action, and necessitates a very large balance arc.

Low angled pallets (*i.e.*, pallets having but little motion) and small balance arcs are preferred for fine watches, the low angled pallets as being less affected by changes in the condition of the oil which is used to lubricate the faces of the pallets than when the motion is greater, and the small balance arc because it allows the balance to be more perfectly detached from the escapement. With less than 30° of balance arc a different arrangement must be made for the safety action. A second roller about one-half the diameter of the one in which the impulse pin is fixed, is mounted on the balance staff for the purpose, and a small gold finger projecting far enough to reach the edge of the smaller roller is screwed to the lever. With a double roller escapement, pallets with 8° of motion are generally used, giving with a lever and roller of 3 to 1 a balance arc of but 24°.

Besides getting a sound safety action with small balance arc, the double roller has three other advantages. (1) The impulse is given more nearly on the line of centres. (2) The safety roller being of a lesser diameter the safety pin when in contact with it offers less resistance to the motion of the balance, and (3) The requisite amount of shake between the safety roller and banking pins is obtained with less run on the pallets. 9° and 10° pallets are sometimes used with a double roller escapement, and the smaller roller is but little less than the other. An escapement made in this way really appears to lose most of the advantages of the extra roller. On the other hand, low angle pallets are sometimes used with a long lever to get increased balance arc. This also is objectionable, for the pallets must have more draw to pull the longer lever up to the banking, and more draw means harder unlocking. It is really only to watches of a high character throughout that double roller escapements with low angled pallets and small balance arcs should be applied. For the ordinary run of work the single roller escapement with 10° or 11° pallets and a balance arc of about 35° is well suited.

Size of the Lever Escapement.—Lever escapements are classed by the trade into the following sizes:—

No. 0 in which	the Escape	Wheel	is	·185	of an inch	in diameter.
1	”	”	”	·205	”	”
2	”	”	”	·225	”	”
4	”	”	”	·245	”	”
6	”	”	”	·265	”	”
8	”	”	”	·285	”	”
10	”	”	”	·295	”	”
12	”	”	”	·305	”	”

No. 1 is the smallest and No. 10 the largest size used in the ordinary run of work. There is no strict rule for the size of an escapement to a watch, but there has been a disposition of late years to use smaller escapements than formerly as they are found to yield better results. In course of time a ridge is formed at the beginning of the impulse planes of the pallets, where the wheel teeth fall. This ridge is more marked and farther along the impulse plane when there is much drop and the escape wheel is large and heavy, because the inertia of the wheel, which increases in proportion to its weight and the square of its diameter, is so great that the balance after unlocking the pallets carries them farther before the wheel acquires sufficient velocity to overtake them. The practice of some of the best London makers is for 6 and 8 sized movements No. 2 escapement; for 10 and 12 sized movements, No. 4 escapement; for 14 and 16 sized movements, No. 6 escapement; and for 18 and 20 sized movements, No. 8 escapement. Many manufacturers confine themselves to two sizes, "two's" for repeaters and ladies, and "sixes" for gentlemens' watches. A Coventry watch will be found usually to have a larger escapement than a London watch of the same size.

The escape wheel is of hard well-hammered brass; the pallets are of steel, wider than the wheel, with the acting parts of ruby in the best, and garnet in the commoner escapements. The pallets are slit longitudinally and the stones fixed in with shellac. The Swiss generally insert the stones across the pallets, so that they are visible. The impulse planes are curved so as to present a smaller surface to the wheel. The impulse pin is of ruby, fixed in the roller with shellac; the safety pin of gold, and the banking pins of brass.

In a good lever escapement all the moving parts are extremely light.

Savage's Two Pin Escapement.—With a view to avoid the somewhat oblique action of the impulse pin, Savage introduced the two pin escapement. Instead of the ordinary impulse pin two very small pins are placed in the roller so that one of them begins to unlock just before crossing the line of centres. The passing space for the safety pin instead of being formed like a crescent is a notch into which the safety pin fits and by the time the unlocking is finished the safety has been drawn into the notch and gives the first portion of the impulse. After it has left the notch the impulse is completed by the notch of the lever striking the second small pin in the roller which has by that time reached the line of centres or nearly so. In order to get the safety pin well into the notch this escapement requires pallets having 12° to 15° of motion, which is objectionable, and the lever and roller action is besides a very delicate job and fails if not thoroughly well done, so that, although the idea is taking, this form of the escapement has never come much into use.

The unlocking nearer the line of centres is also accomplished in what is called the anchor or dovetail escapement, in which the impulse pin is wider than usual and of a dovetailed form. It is open to the objection that, on account of the increased width of the impulse stone and of the lever, banking will occur with a smaller vibration of the balance than with the usual form.

Resilient Escapements.—A watch balance in general use rarely vibrates more than a turn and a half, that is three-quarters of a turn each way, yet occasionally from pressing on the key after the watch is wound in going barrel work, sudden movements of the wearer, or other cause of disturbance, the balance will swing round till the impulse pin knocks the *outside* of the lever. If this banking is violent the time-keeping of the watch is deranged and a broken pivot may also result if the pivots are small. To obviate the evil of such banking various plans have been tried. The most usual is to make the banking pins yield to undue pressure and allow the impulse pin to pass the lever, the wings of which are omitted. Mr. J. F. Cole devised a resilient escapement without any banking pins, in which the teeth of the escape wheel were so formed as to resist the entrance of the pallet into the wheel more than was required for ordinary locking. In the event of banking, the pallet compelled the escape wheel to recoil so that the main spring was really utilized as a spring banking. But in the use of any of these resilient arrangements there is a danger of "setting." When the banking is so violent that the impulse pin drives the lever before it all is well, but it is sure to happen sometimes that just as the impulse pin is passing the lever its motion is exhausted and it jambs against the point of the lever and stops the watch. In a recent arrangement Mr. School claims to have overcome this tendency to set by using very weak spring bankings.

Varieties of the Lever Escapement.—The Swiss and indeed most foreign watchmakers form the tips of the teeth of the escape wheel into inclined planes so as to divide the impulse between the wheel teeth and the faces of the pallets. It is urged that the wheel is not so fragile made in this way, that less drop is required, and that the oil is not drawn away from the tip of the tooth by capillary attraction. On the other hand, English watchmakers maintain that when the planes of the wheel and pallet nearly coincide the increased surface presented to the varying influence of the adhesion of the oil is a serious evil. With brass wheels the impulse faces on the wheel get cut into ruts, but the Swiss avoid this by using steel wheels. Swiss escapements are as a rule commendably light, but the levers are disproportionately long. The Germans make an escapement in which the whole of the impulse plane is on the wheel teeth, the pallets being small round pins. This certainly seems a cheaper and simpler form. In most foreign lever escapements and occasionally in English the roller is planted in a line with the escape wheel and pallet staff holes instead of as shown in the drawing. Although this has provoked controversy there is really no advantage either way except as a matter of convenience in arranging the caliper of the watch or in manufacturing the parts.

Pallets with Equi-Distant Lockings.—The drawing shows the pallets at an equal distance from their centre of motion and they are generally made so. But then, although the impulse planes are equal, the locking faces are not the same distance from the centre and the locking resistance is therefore unequal. Pallets are occasionally made having the lockings equi-distant. Although advocated by Grossmann and other authorities they are but seldom used.

The action of the wheel tooth on the impulse plane of the entering pallet before the line of centres is an engaging action and on the exit pallet after the line of centres a disengaging action. The friction is therefore greater on the entering pallet and when an escapement sets on one impulse face it is in nine cases out of ten the impulse face of the entering pallet. From this it is argued by some that if either pallet should be placed farther from the centre of motion it should not be the exit but the entering pallet, so as to give it a more favourable leverage wherewith to encounter the greater friction which undoubtedly exists. But there is really no advantage in the longer arm, for it has to be pushed through a greater distance by the wheel tooth than the shorter one. Arrange the length of the pallet arms how you will you get but the force of the wheel passing through half the distance between two teeth. As far as the relative adhesion to the oil goes the advantage is with the shorter arm.

Examination of the Lever Escapement.—See that the balance staff is perfectly upright. See that the wheel is perfectly true on edge and on face, and that the teeth are equally divided and smooth. Also by gently turning the wheel backwards see that the pallets free the backs of the teeth. If the wheel is out of truth it must be set up in the lathe and re-bored. It can be fixed either with shellac or in a brass sink bored out the exact size to receive it. If the divisions are unequal or the wheel has some thick teeth it should be discarded. It is useless to attempt to make the wheel right, and to reduce the corners of the pallet to free the wheel is simply to spoil the escapement for the sake of the wheel. At the same time, it must be left to the operator to judge whether the amount of the inaccuracy is serious. The whole affair is so minute that no rule can be given.

Is the wheel the right size? If the lockings are too light and the greater part of the drop INSIDE, the wheel is too small, and should be replaced by one larger. Before removing the wheel, gently draw the balance round till the point of the tooth is exactly on the locking corner, and see if there is ample shake. If not it will be prudent to have the new wheel with the teeth a little straighter than the old ones. If the lockings are too deep and most of the drop OUTSIDE, the wheel is too large and should be topped. The wheel is so fragile that care is required in topping, which is done by revolving it in the turns against a diamond or saphire file.*

Some examiners keep a small copper roller charged with diamond powder for topping. The wheel and roller are then put in the depth tool and the roller revolved against each tooth in succession. This method involves less danger of injury to the wheel. If the wheel is the right size and there is no shake (which try as before directed) the discharging corner of the pallets may be rounded off by means of a diamond file if they are of garnet. If they are of ruby they may be held against an ivory mill charged with diamond powder. If the lockings are too light and there is but little shake they may be made safe by polishing away the locking face a sufficient quantity. If one locking is right and one is too light, the one that is too light may be made safe by polishing away the locking face as before, or the pallet may be warmed and the stone brought out a bit. The locking faces of the pallets should be sufficiently undercut to draw the lever to the banking pins without hesitation. If they require alteration in this respect polish away the upper part of the locking faces so as to give more draw, leaving the locking CORNER quite untouched. But proceed with great care, lest in curing this fault the watch sets on the locking, as small watches with very light balance are very liable to do. If a watch sets on the lockings, or on one of them, the locking face or faces may be polished away so as to give less draw—*i.e.*, have most taken off the CORNER of the locking. If the watch sets on the impulse, the impulse face may be polished to a less angle if the locking is sufficiently deep to allow of it. For it must be remembered that in reducing the impulse the locking of the opposite pallet will also be reduced. In fact, the greatest caution should be exercised in making any alteration in the pallets.

See that the pivots are well polished, of proper length to come through the holes and neither bull headed nor taper. A conical pivot should be conical only as far as the shoulder; the part that runs in the hole must be perfectly cylindrical. They must have perceptible and equal side shake, or if any difference be made the

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* In planting the wheel and pallets it is always best to err, if at all, by making them too deep rather than too light. If they are a shade deep topping the wheel soon puts matters right.

pallet pivots should fit the closest. Both balance staff pivots should be of exactly the same size, The end shakes should all be equal. Bad pivots, bad uprighting, excessive and unequal shake in the pivots are responsible for much of the trouble experienced in position timing. With unequal end shakes the pallet depth is liable to be altered owing to the curved form of the pallet faces. The action of the escapement will also be affected, if the end shakes are not equal, by a banking pin slightly bent, a slight inaccuracy in uprighting and other minute faults. The infinitesimal quantity necessary to derange the wheel and pallet action may be gathered from the fact that a difference of ·002 of an inch is quite enough to make a tripping pallet depth safe or correct depth quite unsound.

See that the escapement is in beat. When the balance spring is at rest the impulse pin should be on the line of centres, that is in the middle of its motion If this is not so the balance spring collet must be twisted round on the staff till it is right.

When the wheel and pallets are right see that the impulse pin is in a line with an arm of the balance and proceed to try if the lever is fixed in the correct position with relation to the pallets. Gently move the balance round till the tooth drops off the pallet. Observe the position of the balance arm and see if it comes the same distance on the other side of the pallet hole when the other pallet falls off. If not the pins connecting pallet and lever are generally light enough to allow of the lever being twisted. See that the pallets are quite firmly fixed to the lever and that the lever and pallets are perfectly in poise. This latter is an essential point in a fine watch to be timed in positions but is often neglected.

Is the roller depth right? If the safety pin has insufficient freedom while there is enough run, the roller is probably planted too deep. On the other hand, if it is found that while the safety pin has plenty of freedom there is no shake between the bankings the roller depth is probably too shallow. When the impulse pin is led round there should be an equal clearance all round the inside of the horn, and the pin must fall safely in to the notch. If it binds in the horn and bottoms in the notch it is too deep, and, on the other hand, if with excessive clearance in the horn the pin when it falls does not pass well into the notch it is too shallow. The readiest method of altering is to warm the roller and shift the impulse pin. See as it passes round that the impulse pin is free in the notch. Just as the safety pin is about to enter the crescent the impulse pin must be well inside of the horn. In the single roller escapement a very little horn is required unless the crescent has been made of an unnecessary width. In very common work one occasionally sees a flat filed on the edge of the roller instead of a crescent. There is no excuse for such a piece of bungling.

See to the safety action. When the tooth drops on to the locking the safety pin should be just clear of the roller. If it is not clear the edge of the roller should be polished down till it is right. If there is more than clearance the safety pin must be brought closer to the roller. See upon pressing the safety pin against the roller that the tooth does not leave the locking and that the impulse pin is free to enter the notch without butting on the horn of the lever; also that the safety action is sound, so that the pin is in no danger of passing the roller. If the action is not sound the diameter of the roller should be reduced and the pin brought towards it sufficiently to get a sound action if it can be done, but if the escapement has been so badly proportioned as not to allow of a sound action being obtained in this way the pin must be shifted forward and the bankings opened to allow more run.

See if the banking pins are so placed as to allow of an equal run on each side. If not they should not be bent, for with bent banking pins a difference in the end shakes of the pivots will cause a difference in the run. The banking pin allowing of the most run should be removed and the hole broached out to receive a larger pin.

The Chronometer Escapement.

(Invented by Le Roy about 1765. Perfected by Earnshaw and Arnold about 1780.)

The Chronometer Escapement, which is unexcelled for timekeeping, is represented in Fig. 17.

Action of the Escapement.—A tooth of the escape wheel is at rest on the locking pallet. The office of the discharging pallet is to bend the detent so as to allow this tooth to escape. The discharging pallet does not press directly on the detent but on the free end of the gold spring, which in its turn presses on the tip of the horn of the detent.

The balance, fixed to the same staff as the rollers, travels in the direction of the arrow around the rollers, with sufficient energy to unlock the tooth of the wheel which is held by the locking pallet. Directly the detent is released by the discharging pallet it springs back to its original position, ready to receive the next tooth of the wheel. There is a set screw to regulate the amount of the locking on which the pipe of the detent butts. This prevents the locking pallet being drawn further into the wheel. It is omitted in the drawing for clearness. It will be observed that the impulse roller is planted so as to intersect the path of the escape wheel teeth as much as possible, and by the time the unlocking is completed the impulse pallet will have passed far enough in front of the escape wheel tooth to afford it a safe hold. The escape wheel, impelled by the mainspring in the direction of the arrow, overtakes the impulse pallet and drives it on until the contact between them ceases by the divergence of their paths. The wheel is at once brought to rest by the locking pallet and the balance continues its excursion, winding up the balance spring as it goes, until its energy is exhausted.

After the balance is brought to rest, it is started in its return vibration by the effort of the balance spring to return to its state of rest. You will notice that the nose of the detent does not reach to the end of the gold spring, so that the discharging pallet in this return vibration merely bends the gold spring without affecting the locking pallet at all. When the discharging pallet reaches the gold spring the balance spring is at rest; but the balance does not stop, it continues to uncoil the balance spring until its momentum is exhausted, and then the effort of the balance spring to revert to its normal state induces another vibration; the wheel is again unlocked and gives the impulse pallet another blow.

Although the balance only gets impulse in one direction, the escape wheel makes a revolution in just the same time as with a

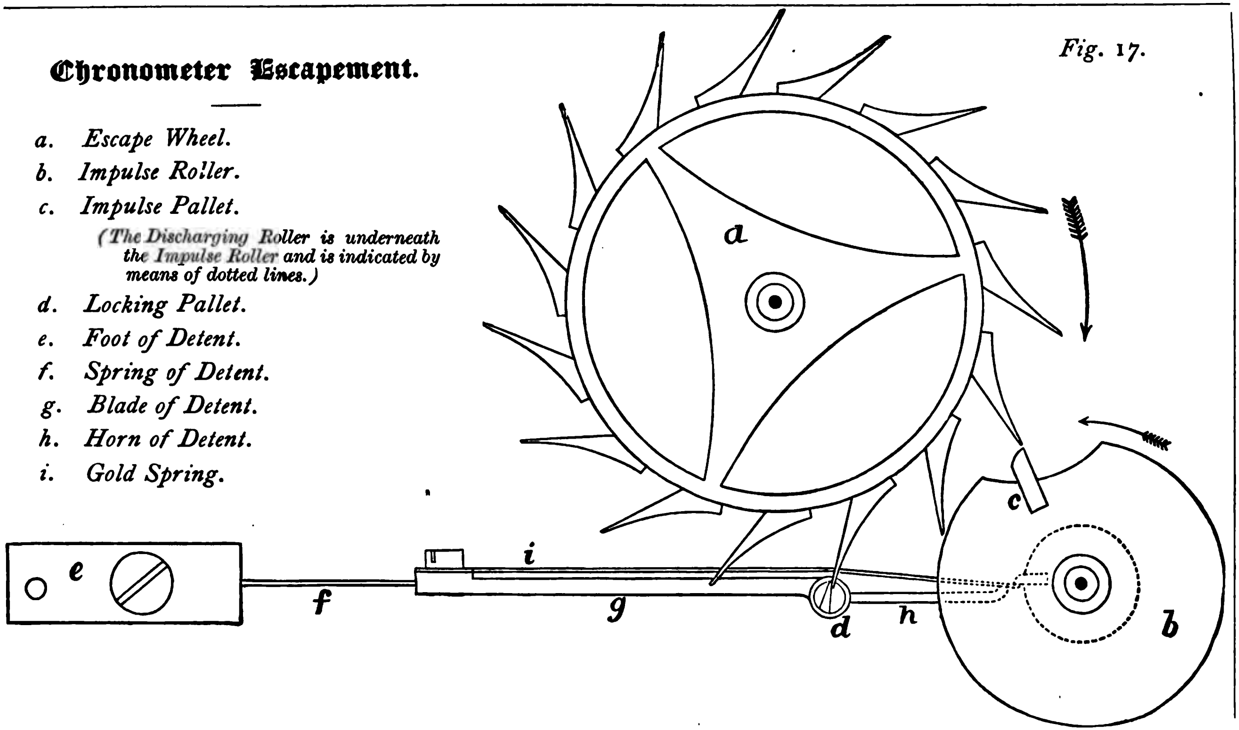
Fig. 17.

Chronometer Escapement.

a. *Escape Wheel.*
b. *Impulse Roller.*
c. *Impulse Pallet.*

(*The Discharging Roller is underneath the Impulse Roller and is indicated by means of dotted lines.*)

d. *Locking Pallet.*
e. *Foot of Detent.*
f. *Spring of Detent.*
g. *Blade of Detent.*
h. *Horn of Detent.*
i. *Gold Spring.*



lever escapement, because in the chronometer the space of a whole tooth passes every time the wheel is unlocked.

By receiving impulse and having to unlock at every other vibration only, the balance is more highly detached in the chronometer than in most escapements, which is a distinct advantage. No oil is required to the pallets and another disturbing influence is thus got rid of. If properly proportioned and well made its performance will be quite satisfactory as long as it is not subjected to sudden external motion or jerks. For marine chronometers it thus leaves but little to be desired, and even for pocket watches it does well with a careful wearer, but with rough usage it is liable to set, and many watchmakers hesitate to recommend it on this account. It is much more costly than the lever and would only be applied to very high priced watches, and in these the buyer naturally resents any failure of action. Its use in pocket pieces is therefore nearly confined to such as are used for scientific purposes or by people who understand the nature of the escapement, and are prepared to exercise care in wearing the watch. There is another reason why watchmakers, as a rule, do not take kindly to the chronometer escapement for pocket work. After the escapement is taken apart the watch does not so surely yield as good a performance as before. In fact it is more delicate than the lever.

Construction and Proportion of the Escapement.—For the ordinary 3-inch two day marine chronometer movements three sizes of escape wheels are used—viz., ·54, ·56 and ·58 of an inch in diameter; for 8-day marine chronometers the sizes are—·48, ·50, or ·52 of an inch. The escape wheel has fifteen teeth, and the diameter of the impulse roller is half that of the escape wheel. The roller is planted as close between two teeth of the escape wheel as possible, so that theoretically the roller intersects the path of the teeth for 24° of the circumference of the wheel. If you draw it out you will see that this gives a balance arc of 45°.* Practically it is less; there must be clearance between the roller and wheel teeth, an allowance must also be made for the side shake of the pivots. In the drawing you will see that the impulse pallet is just opposite a tooth of the escape wheel when the discharging pallet is resting on the end of the gold spring. The balance moves through about 5° to accomplish the unlocking, and by the time that is done the impulse pallet will be 5° in advance of the tooth and the tooth will drop through this space and more before it reaches the pallet, because after the wheel is unlocked it takes some time to get into motion at all, and at first its motion is slower than the motion of the pallet, which had not ceased to travel. The drop must be enough to allow the pallet to safely intersect the path of the tooth, and is arranged generally as shown, so that the pallet is

5° in advance of the tooth when the unlocking is completed. But many authorities insist on even more drop so as to give the impulse more nearly on the line of centres. It is argued that the drop is not all mischevious loss of power as it is in the lever escapement, for with a greater amount of drop the wheel attains a greater velocity when it does strike the pallet. However, most makers adhere to the 5°, although it may in some instances be advisable to vary it. If there is fear of overbanking, the arc of vibration may be reduced by giving more drop; and if the vibration is sluggish and the drop can be safely reduced the vibration will be increased thereby.

The body of the escape wheel is thinned down to about one half for lightness. The fronts of the wheel teeth diverge about 20° from a radial line so that the tips, being more forward, draw the locking stone safely in. The locking face of the stone is also set at a sufficient angle to ensure perceptible draw. The edge of the impulse roller acts as a guard to prevent the wheel teeth passing in the event of accidental unlocking at the wrong time. There is a crescent shaped piece cut out of the roller to clear the teeth of the wheel. It should be very little behind the pallet, and less than the distance between two teeth of the escape wheel in front of it, to avoid the danger of running through or passing two teeth when such accidental unlocking occurs. It is important to see that there is enough cut out in front of the pallet to clear the wheel tooth at all times. When the balance is travelling very quickly—*i.e.*, with an unusually large vibration—the pallet gets a long way in front of the tooth before the tooth starts, and then if the crescent is not cut far enough beyond the face of the pallet the tooth would butt on the roller.

The radius of the discharging pallet is from one-third to a trifle less than one-half of the impulse pallet.

The detent is made very light, and of about the proportion shown in the drawing. The spring of the detent is thinned down so that when the foot is fixed and it stands out horizontally one pennyweight hung from the pipe deflects it about a quarter of an inch. If the spring is made too thin it will cockle and give trouble. The detent may very easily be made too long from the point where it bends to the locking pallet, and would then be too sluggish and allow the wheel to trip by not returning quick enough after the unlocking to receive the next tooth of the wheel. The distance from the shoulder of foot to pipe to be equal to the diameter of the wheel is recommended by Mr. T. Hewitt as a very good rule.

The escape wheel is of hard hammered brass, the rollers of steel. The detent of steel, carefully tempered, with the point of the

* The balance arc is the amount that the edge of the impulse roller intersects the path of the wheel teeth, and is measured from the centre of the balance staff.

horn left softer to allow of bending. The pallets are all of sapphire or ruby, fastened in with shellac. A brass plug is fitted in to occupy the space in the pipe of detent not filled by the locking pallet. The gold spring is hammer-hardened.

Pocket Chronometer.—The escape wheel for pocket chronometers varies from ·28 to about ·35 in diameter. The impulse roller is made larger in proportion than in the marine chronometer to obviate the tendency of the escapement to set. If the chronometer escapement is brought to rest by external motion just as the unlocking is taking place *it must set,* for the balance spring is then quiescent. In the lever escapement the tooth of the escape wheel is in the middle of the impulse plane of the pallet when the balance spring is quiescent, and in this respect the lever has the advantage. If the velocity of the balance in a chronometer is much reduced when the unlocking is completed then a large impulse roller is of great assistance to the wheel in overcoming the inertia of the balance.

As the diameter of the roller is increased the balance arc and also the intersection of the path of the wheel teeth by the impulse pallet is decreased. The velocity of the edge of the roller, too, more nearly approaches the velocity of the wheel tooth. It is, therefore, not prudent to adopt a much less balance arc than 28° or 30°.

The tendency of pocket chronometers to set is also lessened by adopting a quick train. 18,000 is the usual train, but they are occasionally made with 19,200 by having sixteen teeth in the escape wheel instead of fifteen. This seems to be an objectionable way of getting the quick train. The teeth of the escape wheel being closer together a smaller roller must be used to get the same intersection, and as there is less time for the detent to return there is greater danger of mislocking.

The other parts of the Pocket Chronometer Escapement are similar to those of the Marine Chronometer already described.

To Examine the Escapement.—See that the wheel is true and the teeth smooth and perfect, and that the rollers properly fit the staff. See that the end shakes and side shakes are correct. See that the "lights" between the wheel teeth and the edge of the roller are equal on both sides when the wheel is locked. If they are not the foot of the detent must be knocked a trifle to or from the centre of the roller till the lights are equal. If the light is more than sufficient for clearance the roller must be warmed to soften the shellac, and the impulse pallet moved out a little. If the light is excessive there will be too much drop on to the locking after the wheel tooth leaves the impulse pallet, and with a large drop there is danger of tripping.

To ensure safe locking the detent should be set on so that when the banking screw is removed and the locking pallet is free of the wheel teeth it will just spring in as far as the rim of the wheel.

The gold spring should point to the centre of the roller. Bring the balance round till the discharging pallet touches the gold spring preparatory to unlocking, and notice how far from that point the balance moves before the gold spring drops off the face of the pallet. Then reverse the motion of the balance and see if the same arc is travelled through from the time the *back* of the pallet touches the gold spring till it releases it. If not, the horn of the detent must be bent to make the action equal.

Bring the discharging pallet on to the gold spring, and let it bend the detent, so that the locking stone is as much outside the wheel as it was within when the wheel was locked. The gold spring should then drop off the discharging pallet. Make it to length, sloping off the end from the side on which the pallet falls to unlock, and finish it with great care. The gold spring should be thinned near its fixed end as much as possible, and the detent spring thinned if it is needed. The judgment of the operator must determine the proper strength in both cases. The nose of the detent horn should be nicely flattened and the corners rounded off.

The locking pallet should not be perfectly upright. It should lean a little from the centre of the wheel, and a little towards the foot of the detent so that the locking takes place at the root of the stone, and then the action of locking and unlocking does not tend so much to buckle the detent. The face of the impulse pallet, too, should be slightly inclined so that it bears on the upper part of the wheel teeth. By this means the impulse pallet will not mark the wheel in the same spot as the locking pallet.

Try if the escape wheel teeth drop safely on the impulse pallet by letting each tooth in succession drop on, and after it has dropped turn the balance gently backwards; you can then judge if it is safe by the amount the balance has to be turned back before the tooth leaves the pallet. If some teeth do not get a safe hold the impulse roller must be twisted round on the arbor to give more drop.

If the escapement is in beat, the balance when the balance spring is at rest, will have to be turned round an equal distance each way to start the escapement. When the balance spring is in repose the back of the discharging pallet will be near the gold spring, and if the balance is moved round till the gold spring falls off the back of the pallet and then released, the escapement should start of itself; and in the other direction also if the balance is released directly the wheel tooth leaves the face of the impulse pallet, the escapement should go on of itself.

The Horizontal Escapement.

(Invented by Tompion or Graham about 1700.)

This is essentially a frictional as distinguished from a detached escapement. It performs fairly well and is just suited for the lower grades of watches. The vibrations of the balance are not so much affected by inequality in the force transmitted and other faults if the escapement is a frictional one and the work comparatively coarse as when a highly detached escapement and very fine pivots are used. It is certainly remarkable that English watchmakers should have been so baffled by a constructional difficulty as to throw aside the horizontal escapement. Mudge and other eminent English makers used hard brass for the escape wheel and ruby for the cylinder, but without overcoming the tendency to cutting and excessive wear of the acting surfaces. It remained for the Swiss to bring the problem to a successful issue by making both wheel and cylinder of steel and hardening them. The production of the horizontal escapement is now monopolized by the Swiss and the French, who, with the aid of machinery, manufacture the escape wheels and cylinders for an almost incredibly low price.

Action of the Escapement.—Fig 18 is a plan of the horizontal escapement, in which the point of a tooth of the escape wheel is pressing against the outside of the shell of the cylinder. As the cylinder, on which the balance is mounted, moves round in the direction of the arrow the wedge shaped tooth of the escape wheel pushes into the cylinder, thereby giving it impulse. The tooth cannot escape at the other side of the cylinder, for the shell of the cylinder at this point is rather more than half a circle, but its point rests against the inner side of the shell till the balance completes its vibration and returns, when the tooth which was inside the cylinder escapes, and the point of the succeeding tooth is caught on the outside of the shell. The teeth rise on stalks from the body of the escape wheel and the cylinder is cut away just below the acting part of the exit side, leaving only one fourth of a circle in order to allow as much vibration as possible. This will be seen very plainly on examining Fig. 19, which is an elevation of the cylinder to an enlarged scale.

Proportion of the Escapement.—The escape wheel has fifteen teeth, and the outside diameter of the shell of the cylinder is made equal to 13° of the circumference of the wheel. The thickness of the shell is equal to 1°. This fixes the length of the tooth, which

Horizontal Escapement.

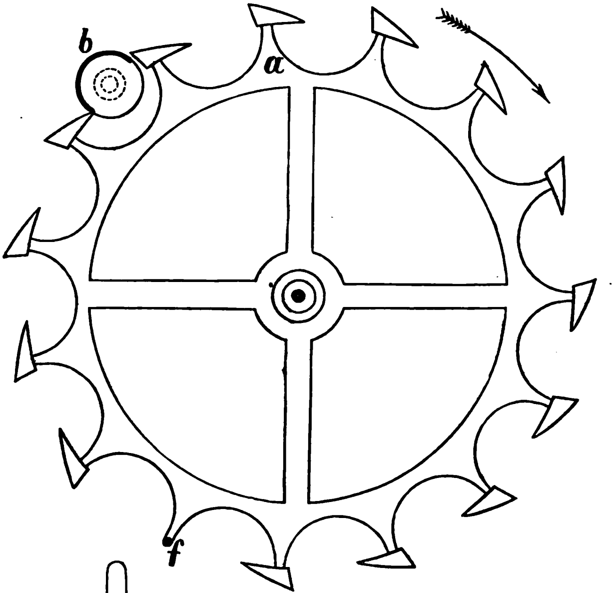


Fig. 18. Plan.

a. Escape Wheel.
b. Cylinder.
c. Entering Lip of Cylinder
d. Exit Lip of Cylinder
e. Passage for Escape Wheel.
f. Tooth removed showing the Stalk on which Teeth are supported.
g. Collet for Balance.

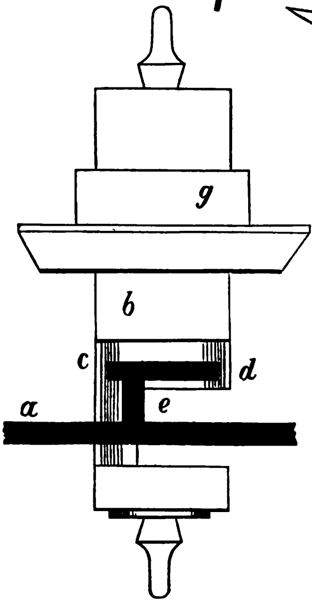


Fig. 19. Elevation of Cylinder and One Tooth of Escape Wheel therein.

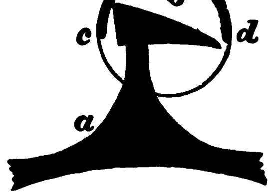


Fig. 20. Plan of Cylinder and One Tooth of Escape Wheel therein.

if made 11° just fills up the inside of the cylinder and allows the cylinder to turn between two teeth without drop of which there should be very little. The teeth are formed so as to give impulse to the cylinder during from 18° to 28° of its vibration each way. The lower angle is used with large, and the higher angle with small-sized watches. The backs of the wheel teeth diverge from a radial line about 15° to give the cylinder clearance. The cylinder should be planted so that a circle drawn through the middle of the impulse planes of the wheel passes through its centre. The acting part of the shell of the cylinder should be a trifle less than seven-twelfths of a whole circle, with the entering and exit lips rounded as shown in the enlarged plan, Fig. 20, the former both ways, and the latter from the inside only. This rounding of the lips of the cylinder adds a little to the impulse beyond what would be given by the angle on the wheel teeth alone. The diameter of the escape wheel is usually half that of the balance, rather under than over.

Examination of the Escapement.—See that cylinder and wheel are perfectly upright. Remove the balance spring and put the cylinder and cock in their places. Then with a little power on and a wedge of cork under the balance to check its motion, try if all the escape wheel teeth have sufficient drop, both inside and out. If the drop is sufficient inside with none outside the wheel is too small; if the reverse the wheel is too large—that is provided the cylinder is planted the correct depth. If some of the teeth only are without necessary freedom, make a hole in thin sheet brass of such a size that one of the teeth that has proper shake will just enter. Use this as a gauge to shorten the full teeth by. For this purpose use either steel and oilstone dust or a sapphire file, polish well with metal and red stuff, and finish with a burnisher. Be careful to operate on the noses of the teeth only, and round them both ways so that a mere point is in contact with the cylinder. If the inside drop is right and there is no outside drop with any of the teeth, although it would indicate a wheel too small it may be prudent to change the cylinder for one of the same inside diameter but thinner, rather than remove the wheel, for it often happens that a larger wheel would not clear the fourth pinion.

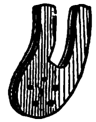
If the teeth of the escape wheel are too high or too low in passing the opening of the cylinder, the wheel should be placed on a cylinder of soft brass or zinc small enough to go inside the teeth, with a hole through it and with a slightly concave face. A hollow punch is placed over the middle of the wheel while it is resting on the concave face of the brass or zinc cylinder, and one or two light taps with a hammer will bend the wheel sufficiently. In fact care must be taken not to overdo it. It rarely happens that the wheel is free neither of the top nor bottom plug, but should this be the case sufficient clearance may be obtained by deepening the opening with a steel polisher and oil-stone dust or with a sapphire file. A cylinder with too high an opening is bad, for the oil is drawn away from the teeth by the escape wheel.

If a cylinder pivot is bent it may very readily be straightened by placing a *bouchon* of a proper size over it.

When the balance spring is at rest the balance should have to be moved an equal amount each way before a tooth escapes. By gently pressing against the fourth wheel with a peg this may be tried. There is a dot on the balance and three dots on the plate to assist in estimating the amount of lift. When the balance spring is at rest the dot on the balance should be opposite to the centre dot on the plate. The escapement will then be in beat, that is provided the dots are properly placed, which should be tested. Turn the balanee from its point of rest till a tooth just drops, and note the position of the dot on balance with reference to one of the outer dots on the plate. Turn the balance in the opposite direction till a tooth drops again, and if the dot on balance is then in the same position with reference to the other outer dot, the escapement will be in beat. The two outer dots should mark the extent of the lifting, and the dot on balance would then be coincident with them, as the teeth dropped when tried in this way, but the dots may be a little too wide or too close, and it will, therefore, be sufficient if the dots on balance bears the same *relative* position to them as just explained; but if it is found that the lift is unequal from the point of rest the balance spring collet must be shifted in the direction of the least lift till the lift is equal. A new mark should then be made on the balance opposite to the central dot on the plate.

When the balance is at rest the banking pin in the balance should be opposite to the banking stud in the cock so as to give equal vibration on both sides. This is important for the following reason. The banking pin allows nearly a turn of vibration, and the shell of the cylinder is but little over half a turn, so that as the outside of the shell gets round towards the centre of the escape wheel the point of a tooth may escape and jamb the cylinder unless the vibration is pretty equally divided. When the banking is properly adjusted bring the balance round till the banking pin is against the stud; there should then be perceptible shake between the cylinder and the plane of the escape wheel. Try this with the banking pin first against one and then against the other side of the stud. If there is no shake the wheel may be freed by taking a little off the edge of the cylinder where it fouls the wheel by means of a sapphire file, or a larger banking pin may be substituted at the judgment of the operator. See that the banking pin and stud are perfectly dry and clean before leaving them, a sticky banking often stops a watch. If the watch persistently banks it is an indication that the balance is too light; to meet this fault a weaker mainspring may be used, or a larger balance, or a wheel with a smaller angle of impulse. By far the quickest and best way is to *very slightly* top the wheel by holding a piece of Arkansas stone against the teeth, afterwards polishing with boxwood and red stuff. So little taken off the wheel in this way as to be hardly perceptible will have great effect.

Running in a Cylinder.—Many different methods of procedure are adopted for running in a cylinder. The following, recommended by Mr. Schoof, is, from his experience, worthy of consideration. Remove both cocks, and screw a brass plate of this shape in place of the bottom one, so that one of the holes is in the position of bottom jewel. Select a suitable cylinder, and put it in the frame with the arbor going through hole in piece of brass upon which rests the body of cylinder. Let a tooth



of escape wheel pass into cylinder, which turn round till the plane of wheel is in the slit of cylinder. If the cylinder is too high turn away the bottom of the body. Mark exact height for balance just above bar of escape wheel. Reduce lower arbor of cylinder to thickness of bottom cock. Screw both cocks to their places, take whole length with pinion guage and make cylinder to it by shortening upper arbor. To give strength to the cylinder fill it with shellac when the proper height for wheel teeth has been taken.

The Duplex Escapement.

(Invented about 1780. Credited to Dutertre, Tyrer, and others.)

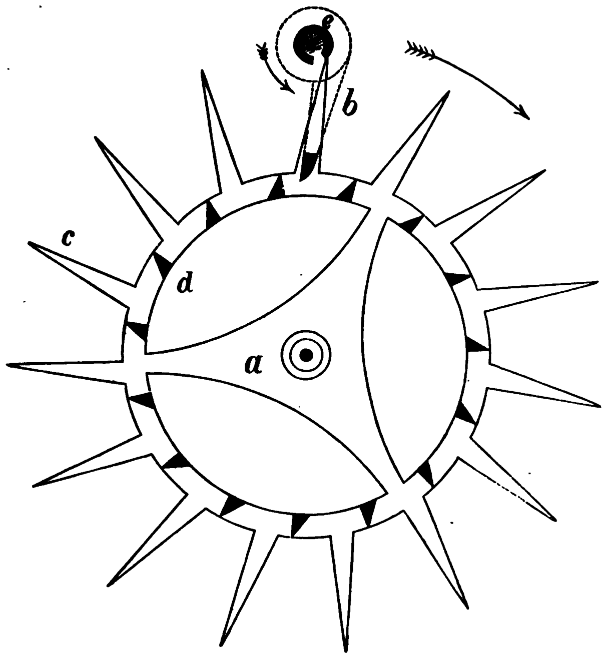
This, like the Chronometer, is a single beat escapement, that is, it receives impulse at every other vibration only. It is shown in Fig. 21. The escape wheel has two sets of teeth. Those farthest from the centre lock the wheel by pressing on a hollow ruby cylinder or roller fitted round a reduced part of the balance staff, and planted so that it intercepts the path of the teeth. There is a notch in the ruby roller, and a tooth passes every time the balance in its excursion in the opposite direction to that in which the wheel moves, brings this notch past the point of the tooth resting on the roller. When the tooth leaves the notch, the impulse finger, fixed to the balance staff, receives a blow from one of the impulse teeth of the wheel. The impulse teeth are not in the same plane as the body of the wheel, but stand up from it so as to meet the impulse finger. There is no action in the return vibration. In the figure the detaining roller travelling in the direction of the arrow is just allowing a locking tooth of the wheel to escape from the notch and the pallet is sufficiently in front of the tooth from which it will receive impulse to ensure a safe intersection.

The balance is never detached, but the roller on which the wheel teeth rest is very small and highly polished, so that there is but little friction from this cause, and the alteration in its amount is, therefore, not of such consequence as might be imagined. The escape wheel is made as light as possible of hard hammered brass of very fine quality. The points of the impulse teeth are two-thirds the distance of the points of the locking teeth from the centre of the wheel. The impulse pallet is jewelled.

The staff requires to be planted with great exactness, and one of the most frequent causes of derangement of the Duplex escapement is the wearing of the balance pivots. The pivots repolished, and new holes, or at all events a new bottom hole, is the remedy. See also that the point of each locking tooth is smooth and nicely rounded, and that every impulse tooth falls safely on the pallet; if some are shallow twist the impulse pallet round so as to give more drop. Or if the roller depth is also shallow carefully make the teeth of equal length by topping, and then, supposing it to be a full plate watch, very slightly tap cock and potance towards the wheel until the escapement is made safe. In a three-quarter plate the jewel setting may be scraped away on one side and rubbed over on the other. The extra amount of intersection of the impulse pallet in the path of the wheel teeth thus made can be easily corrected by polishing off the surplus amount, if any.

Duplex Escapement.

Fig. 21.



a. Escape Wheel.
b. Impulse Pallet.
c. Locking Teeth.
d. Impulse Teeth.
e. Ruby Roller.

It is of the utmost consequence in this escapement that all the jewel holes should fit accurately, and that the balance staff should have very little end shake, otherwise the pivots will be found to wear away very quickly.

It sometimes happens that the impulse pallet in running past just catches on the impulse tooth, and when the balance leans towards the escape wheel the continued recurrence of this causes the vibration to fall off and gradually stops the watch. If the locking teeth are already the right depth the fault should be corrected by polishing a very little off the corner of the pallet with a bell metal polisher. But the greatest care must be taken not to overdo it.

When the escapement is in beat the notch in the roller is between the locking tooth resting on it and the line of centres.

The idea of this escapement is seductive, it conforms to the requirement of giving impulse across the line of centres, and at one time it was considered an excellent arrangement, but it has proved to be quite unreliable. The best proportion of its parts, and the finest work are insufficient to prevent it setting. On the introduction of the Lever it declined, and is rarely made now.

The Verge or "Crown Wheel" Escapement.

The Verge, the earliest, probably, of all the escapements, is shewn in Fig 22. It has no pretensions to accuracy in presence of such escapements as the Lever and Chronometer, and yet the demand for watches with Verge escapements has not died out. At all events, they are still made.

The balance in this escapement has no free arc, and its vibration is limited to about 110° each way. The escape wheel, or crown wheel as it is called, has usually either 11 or 13 teeth, and in the plan of the watch its arbor lies horizontally. The balance staff, or verge, is made as small as proper strength will allow, and planted close to the wheel so that the tips of the teeth just clear it. The pallets, which form part of the verge, are placed at an angle of 95° or 100° with each other. The latter angle is generally preferred.

The drawing is a plan of the escape wheel and verge as they lie in the watch. The width of the pallets apart from centre to centre is equal to the diameter of the wheel. A tooth of the escape wheel is just leaving the upper pallet *(c.)*; as it drops off, the under tooth will reach the root of the lower pallet *(d.)*, but the motion of the verge will not be at once reversed. The escape wheel will recoil until the impetus of the balance is exhausted. The teeth of the wheel are undercut to free the face of the pallet during the recoil.

Verge Escapement.

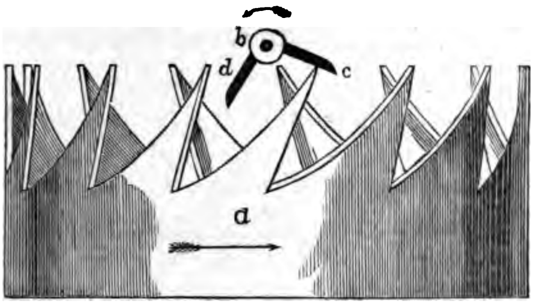


Fig. 22.

a. Escape Wheel. | *b. Verge.* | *c. & d. Pallets.*

Generally in French and occasionally in English watches the pallets are even more open. An increased vibration of the balance and less recoil can be obtained with a larger angle, but to get sufficient impulse the verge must be planted closer to the wheel. This necessitates cutting away a part of the body of the verge to free the wheel teeth. Then, as the wheel tooth impinges on the pallet almost close to the centre of the verge, there is more friction on the pivots and the wheel tooth gets so small a leverage that the escapement often sets unless the balance is very light. On the other hand, with the opening between the pallets only 90°, as it is in many English watches, the vibration of the balance is too small and the recoil too great. An opening of about 100° avoids the drawbacks incidental to the two extremes and may therefore be adopted with advantage.

To ensure good performance the body or arbor of the verge should be upright and when in the frames and viewed through the follower potance hole should be seen crossing the balance wheel hole of the dovetail. The position of the eye should be in a line with the arbor of the balance wheel pinion when in the follower; the drops off the pallets equal, and the balance wheel teeth true.

Balance Springs and Springing.

There are four factors upon which the time of the vibration of the balance depends.

(1) The weight, or rather the mass, of the balance.

* (2) The distance of its centre of gyration from the centre of motion or to speak roughly the diameter of the balance.

(3) The length of the balance spring.

(4) The strength of the balance spring or more strictly its power to resist change of form.

A very generally accepted rule is that the balance spring of a watch should be half the diameter of the balance. The length is also important. By varying the strength of the wire two springs may be produced each of half the diameter of the balance but of very unequal length, either of which would yield the same number of vibrations as long as the extent of the vibration remained constant, yet if the spring is of an improper length, although it may bring the watch to time in one position, it will fail to keep the long and short vibrations isochronous. Then again, a good length of spring for a watch with a horizontal escapement vibrating barely a full turn would clearly be insufficient for a lever vibrating a turn and a half. The outer coil of the flat spring pinned in in the ordinary way comes into action only in the long vibrations, but if instead of following the volute it is curved inwards and fixed nearer the centre of the spring the outer coil is more yielding and

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* The mass of a body is the amount of matter contained in that body and is the same irrespective of the distance of the body from the centre of the earth. But its weight which is mass × gravity varies in different latitudes. The centre of gyration is that point in a revolving body in which the whole of its energy may be concentrated. A circle drawn at seven tenths of its radius on a circular revolving plate of uniform thickness would represent its centre of gyration. The moment of inertia or the controlling power of balances varies as their mass and as the square of the distance of their centre of gyration from their centre of motion. Although not strictly accurate it is practically quite near enough in the comparison of balances to take their weight and the square of their diameter.

a longer spring may be used. This form of spring, called a Breguet, after the inventor, is now much used in the finer class of watches. It distends in action on both sides and the balance pivots are thereby relieved of the side pressure given when the spring is rigid. The Breguet spring, in common with the helical and all other forms in which the outer coil returns towards the centre, offers opportunities of obtaining isochronism by slightly varying the character of the curve described by the outer coil and thereby altering its power of resistance.

The position of the points of attachment of the inner and outer turns of a balance spring in relation to each other has an effect on the power of the spring quite apart from its length. For instance, a very different performance may be obtained with two springs of precisely the same length and character in other respects, but pinned in so that one has exactly complete turns and the other a little under or a little over complete turns. This property, which is more marked in short than in long springs, is depended upon by many for obtaining isochronism. A short spring as a rule requires to be pinned in short of complete turns and a long one beyond the complete turns. In duplex and other watches with frictional escapements, small arcs of vibration and short springs, it will be found that the spring requires to be pinned in nearly half a turn short of complete turns. Marine Chronometer springs are found to isochronise better and act truer when pinned in at about a quarter of a turn short of complete turns.

The centre or eye of the flat spring is operated on by some in order to obtain isochronism, but the eye of the spring allows but little scope for such interference. It should be as small as possible and any distortion of its form is at once apparent.

There is no doubt that the less a spring is "manipulated" the better. Mr. Glasgow contends that the whole question of isochronism resolves itself into the adoption of a spring of the correct length and recommends for a lever watch fourteen turns if a flat and twenty turns if a Breguet spring is used. He argues that if a spring is too short the short vibrations will be fast and the long vibrations slow and that all bending and manipulation of the spring with a view to obtain isochronism are really only attempts to alter the effective length of the spring.

Many who have been in the habit of obtaining isochronism with a lesser number of turns demur to the lengths given because the longer the spring the greater of course will be the temperature error, but the balance of opinion is strongly in favour of using such a length of spring as will give isochronism naturally, and it may be taken therefore as a very good rule that a balance spring should be half the diameter of the balance and with from eight to twelve turns for a horizontal and fourteen turns for a lever; Breguet springs for lever watches twenty turns.

Watch springs of thick and narrow wire are apt to cockle with large vibrations, while springs of wide and thin wire keep their shape and are more rigid. It is of even greater importance that the springs of marine chronometers subjected to the tremor of steamships should be of wide and thin wire.

Helical springs for ordinary two-day marine chronometers are made from ·4 to ·54 of an inch in diameter and about a quarter of a turn short of either eleven, twelve, or thirteen turns. The smaller diameter of spring is advocated on the ground that the acceleration or gaining on their rates often noticed in new chronometers may be avoided with a shorter overcoil. If the overcoil in a watch or chronometer is subjected to any considerable amount of bending the piece is sure to gain on its rate. Some manufacturers expose new chronometers to a high temperature in the oven for a time so as to get them to settle down quickly to a steady rate. Other eminent makers declare there is no benefit in doing so. Mr. T. Hewitt tells me that after a chronometer has been brought to time he has removed the balance spring, collet and stud and subjected them altogether to sufficient heat to lower the colour of the spring without materially altering its form or at all affecting the acceleration of the chronometer.

It is remarkable that while in watches the difficulty is generally to get the short arcs sufficiently fast, precisely the reverse is the case with the marine chronometer, in which the trouble is usually to get the short arcs slow enough. The escapement is not responsible for the difference because pocket chronometers follow the same rule as watches with lever escapements.

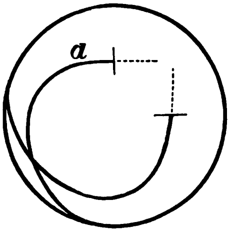


Fig. 23.

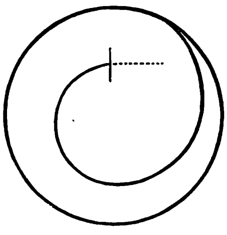


Fig. 24.

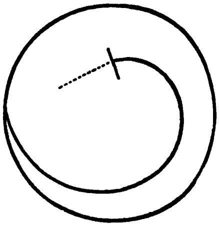


Fig. 25.

Fig. 23 is a careful reproduction of the curves of a marine chronometer spring. *a* is the lower coil. The two short lines crossing the spring denote the face of the collet and the face of the stud respectively, and the dotted lines the direction of the ends of the spring which form nearly a right angle. Occasionally if the short arcs are fast the upper turn is slightly bent just as it enters the stud so as to throw the end outward. The pin is then placed on the inside. Fig. 24 is the lower coil and Fig. 25 the upper coil of a pocket chronometer spring. It will be observed that the sweep is longer than in the marine chronometer and that the lower curve is carried rather farther back into the spring than the upper. The spring makes just complete turns, but the upper turn just as it enters the stud has a slight sharp bend throwing the end inwards. This little bend is of the utmost importance for it has the effect of quickening the short arcs. Pocket chronometer springs are made half the diameter of the balance and from 7 to 10 turns.

Fig. 25 will also serve very well to represent the overcoil of a Breguet spring, although the overcoil is sometimes carried much farther into the spring. In some springs it is not unusual to see the overcoil more than a complete turn in extent. Breguet springs are now often used for pocket chronometers instead of the helical form. Just as good a result can be got with the Breguet as with the helical, and the latter takes up height and in consequence is often made too short. There is though one advantage in using helical springs for pocket chronometers. The escapement may be banked through the spring and this is done more readily in the helical form. Mr. Kullberg's method is to place two nearly upright pins on the balance arm so close to the spring as to prevent it expanding more than is required for a sufficient vibration. These pins should be slightly inclined to the centre so as to touch the top of the spring first and thereby stop the balance more gradually.

It should be remembered that if the vibrations of a balance are to be isochronous the impulse must be delivered in the middle of its vibration and that therefore no spring will be satisfactory if the escapement is defective in this particular.

Applying a Flat Spring.—The train decides the number of vibrations required. Divide the number of fourth wheel teeth by number of leaves in escape pinion; multiply the quotient by 30 (double the number of escape wheel teeth), the product will be the number of impulses the balance receives in a minute. If it is an 18,000 train the number will be 300, that is 5 beats a second. A 16,200 train gives 270 a minute; 4·5 a second.

Having ascertained the train, put a bit of beeswax about the size of a small pin's head upon the end of the lower staff pivot. The diameter of the spring is decided by the position of the stud hole. Select a spring of suitable size and lay it with its centre well in the centre of cock jewel, so that from the eye to the stud hole makes complete turns, and note where the coil would enter the stud hole. Take hold of it firmly with the tweezers about the distance of the curb pins short of that point. Placing the inner turn under the wax on the pivot you will raise the balance from the board by the inner turn of the spring catching the wax. The least motion of the hand which holds the tweezers will cause the balance to vibrate with an up and down motion, and the number of vibrations in a second will be ascertained by listening to the beat of a regulator. If a watch glass is placed under the pivot the contact of the pivot with the glass will make the vibrations distinctly audible, and the eyes of the operator will be at liberty to watch the regulator. If there are five vibrations a second (with the 18,000 train) there is no doubt the spring will do, if six it is too strong, and if four too weak. If there is any difficulty in counting the number of vibrations to a second a watch making the same number of beats as it is desired the balance under trial should have may be placed to the ear for comparison.

Some practice is required to count accurately the vibrations in a second and many after picking up the balance by means of the bit of wax on the pivot give it half a turn, so that it will vibrate for over a minute, and then count every other vibration till a spring is obtained that gives about 150 double vibrations if it is for an 18,000 and about 135 if for a 16,200 train. When a spring of the right strength is found it may be pinned to the collet. The usual plan of pinning in is to put the collet on a round broach held between the thumb and finger of the left hand while the pin is fitted and the spring pinned on, but it often occurs that the collet turns round on the broach and the pin is not fitted tight enough in consequence. The spring, too, is likely to touch the fingers and in the case of a damp hand the spring would be likely to be spoilt by rusting. Another mode of pinning on is to place the collet on the board paper and put the spring over the collet. With a short piece of boxwood sloped away at the end press the collet on the board, the pin can then be fitted with comfort and without danger of shifting the collet. The pin should be flattened where it presses against the spring and when fitted and made can be pressed in with a small joint pusher. The spring should start away from the collet hole with an easy curve and must not hug the collet or isochronism will be out of the question.

The collet should be put on an arbor with a bow and the spring carefully set true and flat in the turns. In setting the spring it must only be touched close to the eye. The outer coil may then be pinned into the stud at equal turns. Some make a practice of fitting the pin in the stud hole beforehand, breaking off a piece of the waste outer turn of the spring and passing it through the stud hole in order to get the shape of the pin. It will be prudent to first pin the spring in temporarily and notice if the eye is true with the cock jewel If it is not the stud hole had better be broached in the required direction. On no account should a flat spring be bent close to the stud hole to bring the eye right with the cock jewel.

The watch should be tried for say three hours lying and three hours hanging. If it gains in the short vibrations the spring may be taken up, and if it loses in the short vibrations let out a little. But if the alteration has the opposite effect to that desired, as in some instances it may, proceed in the contrary direction. Some recommend opening the curb pins very slightly if the watch gains in the short arcs. This is often done but it is an objectionable practice, for with much play between the curb pins the spring will get worn where they touch and the going of the watch will not be satisfactory. The watch may be brought to time with the index, dividing the remaining error between the long and short vibrations. The curb pins should be only just free of the spring, parallel inside and tapered back from the point on the outside without burr or roughness that would allow a lodgment of the spring.

Soft balance springs soon get out of shape and are therefore not reliable, but their strength is not materially increased by hardening. If a watch is brought to time with a soft spring and the spring is afterwards hardened the rate of the watch would be accelerated but a second or two in twenty-four hours. The method of hardening a spring without distorting it after it had been applied was at one time kept a secret by the few who practised it. It is, however, exceedingly simple. The spring is placed between two round PERFECTLY FLAT plates of German silver. These plates are then laid on a small press of German silver very much resembling in form the presses used for copying letters (see Fig 26). The plates are kept together by means of a screw. The spring, press and all, are then heated to a cherry red and plunged into water. When cool a thin slip of bright steel is laid on the press, which is heated till the slip of steel is brought to a blue colour, when it is plunged into oil. It is not imperative that the press should be of German silver, but it must not be of steel or wrought iron or the springs will be spoiled.

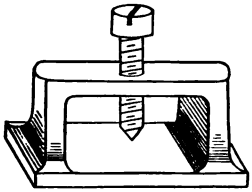


Fig. 26.

Position Errors.—Only the finer class of watches with overcoil spring and compensation balance are as a rule tested for position errors. Position errors, which are due to escapement faults and other constructional inaccuracies, are often confounded with a want of isochronism, but a watch may be perfectly isochronous and yet have very large position errors. Isochronism is dealt with first.

Dial up is generally taken to represent the long vibrations, and any two opposite quarters the short vibrations. Suppose a watch showing meantime and with balance carefully poised is placed dial upwards for 24 hours. At the end of that period it is found to be, say, 8 secs. fast. The variation from meantime + 8 secs. is noted. In the rack with pendent up for twelve hours it is found to have lost 8 secs., and is then again meantime. With pendent down for twelve hours it is found to have lost 2 secs., and is then — 2 secs. The sum of the variation in the long vibrations is expressed by + 8; the sum of the variation in the short vibrations by — 10. The short arcs are said to be slow 18 secs.

The most usual way of making the long and short vibrations isochronous is by altering the form of the overcoil. The piece is afterwards brought to meantime by screwing the meantime screws in or out. If the divergence from meantime is very great two opposite screws of the balance are removed and heavier or lighter one substituted as may be required. When the short arcs are slow, as in this case, the arch of the overcoil is closed slightly and a little more of the body of the spring added to the overcoil. When the short arcs are fast the arch of the overcoil is made a trifle flatter, and a little of the overcoil taken back into the body of the spring. To alter the shape of the overcoil the spring is held with a pair of pliers with brass faces, curved exactly to suit it, while the alteration is made with a similar pair. Alterations must be made very gradually, for if bent too much the spring is likely to be spoilt in bending it back.

After the requisite alteration is made, the watch again set to meantime is found to be with 24 hours trial, dial up, say, 12 secs. fast. The watch is noted + 12 secs. With the pendent up for 12 hours it gains 3 secs., making it + 15 secs. And with the pendent down 12 hours it gains 9 secs., and is then + 24 secs. So that the sum of the variation in the long vibrations is + 12, and the sum of the variation in the short vibrations is + 12 also. The watch is now said to be isochronous, but there is still a position error between pendent up and pendent down of 6 secs. in 12 hours.

Twelve hours trial with pendent to the right shows a gain of 13 secs., and 12 hours trial with pendent to the left a loss of 1 sec., making a position error of 14 secs. in 12 hours in the quarters.

The mean time screws may be drawn out sufficient to give a loss of ten seconds in twenty-four hours, thus dividing the error. The piece would then show a variation from mean time in twenty-four hours running in each position :—

Dial up	+	2 secs.
Pendent up	—	4 ,,
Pendent down	+	8 ,,
Pendent right	+	16 ,,
Pendent left	—	12 ,,

It will be seen that this watch could easily have been brought to time hanging (pendent up) and lying (dial up), but at the cost of the other positions. Open faced watches are never placed dial downwards in ordinary wear and are therefore but rarely tested in that position.

If the short vibrations are not more than a turn in extent the positions may be equalized by drawing out the quarter screws of the balance nearest the fast position (opposite pendant and right of pendant), and setting in the ones nearest the slow position, and this is the remedy generally adopted. If the short vibrations are a turn and a quarter altering the screws will be useless. Should the short vibrations be a turn and a half, which is not very likely, the opposite method would have to be resorted to, viz., the screws opposite the fast positions must be set in and those opposite the slow positions drawn out. This is called "timing in reverse." Many of the best authorities strenuously object to tampering with the balance and prefer to leave the position errors alone. No doubt it is a grave fault to set the balance out of poise, and as the extent of the vibration falls off from thickening of oil and dirt the correction is destroyed and an additional error introduced.

There is another method employed but it is not less objectionable and is not, I believe, efficacious if the position errors are large. It consists of bending the balance spring (not the eye), so that the eye instead of being true with the cock jewel is more towards the fast positions; for instance, in the preceding example the spring would be moved from the pendant and to the right of it. The effect of this is to cause more friction on the balance staff pivots at those points.

In timing a going barrel watch it should be fully wound before each trial, so that the pull of the same turns of the main spring may be compared in every case; for although there should not be much difference whether the short vibrations are caused by decrease of motive power or by change of position from lying to the rack, yet the results will not be absolutely identical. If the discrepancy is very great it would probably indicate defective jewelling; holes too long or too large, or not sufficiently polished.

The length of the straight part of the jewel hole should be about equal to its diameter.

In adjusting marine chronometers and chronometer clocks for isochronism the long and short arcs are not obtained by changing the position of the instrument, but the arc of vibration is reduced about one quarter by letting down the mainspring or reducing the power in any other convenient manner.

The Compensation Balance and Adjusting for Temperature.

Berthoud in 1773 tabulated the effect of temperature upon one of his marine watches, which, in passing from 32° to 92° (Fah.), lost per diem by—

Expansion of the Balance	62 secs.
The loss of Spring's Elastic Force	312 ,,
Elongation of the Spring	16 ,,
	393 or 6 m. 33 s.

Sir G. B. Airy, by experiment in 1859, showed that a chronometer with a plain uncompensated brass balance lost on its rate 6.11 secs. in 24 hours for each degree Fahrenheit of increase in temperature.

To counteract this effect of change of temperature chronometers and fine watches are furnished with a balance which expands and contracts with heat and cold. The halves of the rim are free at one end and fixed at the other to the central arm, which is of steel. The inner part of the rim is of steel and the outer part, which is of brass twice the thickness of the inner, is melted on to the steel. As brass expands more than steel the effect of an increase of tem-temperature is that the brass in its struggle to expand bends the rims inwards, thus practically reducing the size of the balance. With a decrease of temperature the action is reversed. The action, which is very small at the fixed ends of the rim, increases towards the free ends where it is greatest. In a marine chronometer there is one large weight at about the middle of each half rim, which is shifted to or from the fixed end, according as the compensation is found on trial to be less or more than is desired. In pocket chronometers and watches a number of holes are drilled and tapped in the rim and the compensation is varied by shifting screws with large heads from one hole to another, or by substituting a heavier or a lighter screw. In the marine balance there are two screws with heavy nuts on opposite sides of the rim close to the central arm for bringing the chronometer to time. In watch balances there are four such screws placed at equal distances round the rim. These of course are not touched for temperature adjustment.

Fig. 27 shows the Marine Chronometer Balance. The two smaller subsidiary timing screws beside the large ones are sometimes dispensed with. A compensation watch balance is shown in Fig. 28. In all but the finest work the quarter mean time screws are not fitted with nuts but made with heavy heads and screwed into the balance from the outside like the compensation screws. It will be observed that the cuts in the rims of the balances are not radial. The object of cutting them at an angle as shown is that the free end of the rim may be stopped from bending unduly towards the centre when the balance is roughly handled.

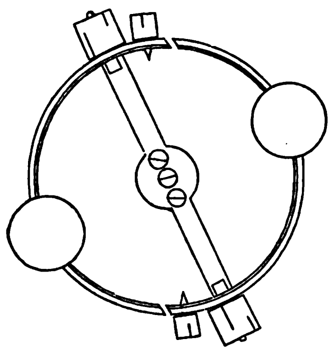


Fig. 27.

Marine Chronometer Balance.

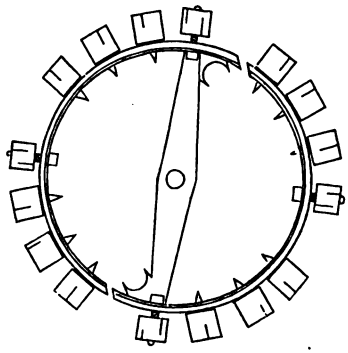


Fig. 28.

Compensation Balance for Watches.

It will be noticed from Berthoud's table that the greater part of the loss in heat is from the loss of elasticity on the balance spring, and Sir G. B. Airy has demonstrated that the loss is uniformly in proportion to the increase of temperature. But the compensation balance fails to meet the temperature error exactly; the rims expand a little too much with decrease of temperature and with increase of temperature the contraction of the rims is insufficient, consequently a watch or chronometer can be correctly adjusted for temperature at two points only. A marine chronometer is usually adjusted at 45° and 90°, unless special adjustment is ordered to suit particularly hot or cold climates. Pocket watches at about 50° and 85°. In this range there would be what is called a middle temperature error of about 2 secs. in twenty-four hours. To avoid this middle temperature error in marine chronometers various forms of compensation balances have been devised and numberless additions or auxiliaries have been attached to the ordinary form of balance for the same purpose.

Compensation Adjustment.—A hot and a cold chamber are required for the temperature adjustment. The "oven" is a box made of sheet copper or iron, generally with a water jacket to the bottom, the exterior of which is heated by means of a gas jet. There is sometimes an automatic gas governor for keeping the temperature uniform. The oven is furnished with a glass door, and, of course, a thermometer. The "ice box" is also a metal chamber, with a receptacle for ice round the sides, and jacketted all over with a non-conductor. The adjustment for temperature is made after observations of the alteration of rate in the two extremes at which it is decided to expose the piece. A short exposure to the temperature, or a single observation cannot be taken as a reliable indication of the effect, for the unnatural connection of the metals composing the rim of the balance requires time to settle.

The usual course is to place the piece to be tested, after its rate has been carefully noted, into the oven. After twenty-four hours the rate is again noted. Say it has gained on its rate 8 seconds. It is then removed to the ice box, and subjected to the other extreme of temperature for 24 hours. At the end of that period a comparison shows that it has lost on its rate 7 seconds. Although the alteration in the two extremes is not equal, there is sufficient evidence that the balance is over-compensated. In the oven the rims bending too far inwards reduced the effective diameter of the balance too much, and caused a consequent gain. In the ice box the rims expanded too much, and as a consequence the piece went slower. If it is a marine chronometer under trial the weights have to be shifted a little towards the fixed end of the rim. They must be shifted equally, or the balance will be thrown out of poise, and it is well to see that the slots in the weights are easy, and do not grip the rim. If a watch is being tested two opposite screws must be shifted towards the fixed end, care being taken not to screw them too tight to the rim.

The piece is then again subjected to the extremes of temperature, and as the compensation adjustment gets closer the piece is taken from the ice box and placed a second time in the oven for verification before the alteration is made. As the trial proceeds the piece is allowed to remain more than 24 hours in each extreme, oftentimes a week.

Rocking Bar Keyless Mechanism.

This is the keyless mechanism most generally adopted in English going-barrel watches. Variations in the construction are made at the judgment of the manufacturers. The arrangement shown in Fig. 29 (page 72), is recommended by Mr. Chalfont.

For winding the watch, connection has to be made between the serrated button projecting above the pendant and the wheel to the left hand of the figure which is attached to the barrel arbor. For setting the hands the winding connection must be broken and connection made with the minute wheel on the right hand of the figure so that it may be actuated in either direction by turning the button. Three wheels gearing together are planted on the rocking bar. The middle one rides freely on a stud which projects from the rocking bar. This stud is pivotted into both plates of the watch and forms the centre of motion of the rocking bar, which is free to move up or down so as to engage with either the barrel wheel or the minute wheel. In its normal position the connection is with the barrel wheel. A spring fixed at one end to the pillar plate presses against a small stud on the rocking bar just sufficiently to keep the winding wheels in gear. A contrate wheel squared on to the stem of the winding button gears with the middle wheel on the rocking bar. As the button is turned for winding the resistance of the barrel wheel ensures the safety of its depth with the wheel on the rocking bar. When the knob is turned the reverse way the teeth of this latter wheel slip over the teeth of the barrel wheel. There is a spring click to prevent the barrel wheel running back. When any strain is thrown on the click the end of it butts against a pin screwed into the plate, but during winding there is a space between this pin and the end of the click so that if the mainspring is wound tightly the wheel is allowed to recoil a little till the end of the click touches the pin. Undue strain is thus taken off the mainspring and there is no fear of overbanking, which is often observed after careless winding where no such provision is made.

Whatever form of click is used it is most important that it should be planted so that the points of two teeth of the barrel wheel are never presented to the wheel on the rocking bar with which it gears. If this precaution is disregarded these wheels will butt on going into action, the winding will be unsatisfactory, and there will be danger of stripping the teeth of the wheels.

For setting hands a push piece projecting through the band of the case is pressed with the thumb nail so as to depress the right hand side of the rocking bar till the wheel on that side engages with the minute wheel. The thumb nail presses on the push piece till the operation of setting the hands is completed, and directly the push piece is released the winding wheels engage again.

Rocking Bar Keyless Mechanism.

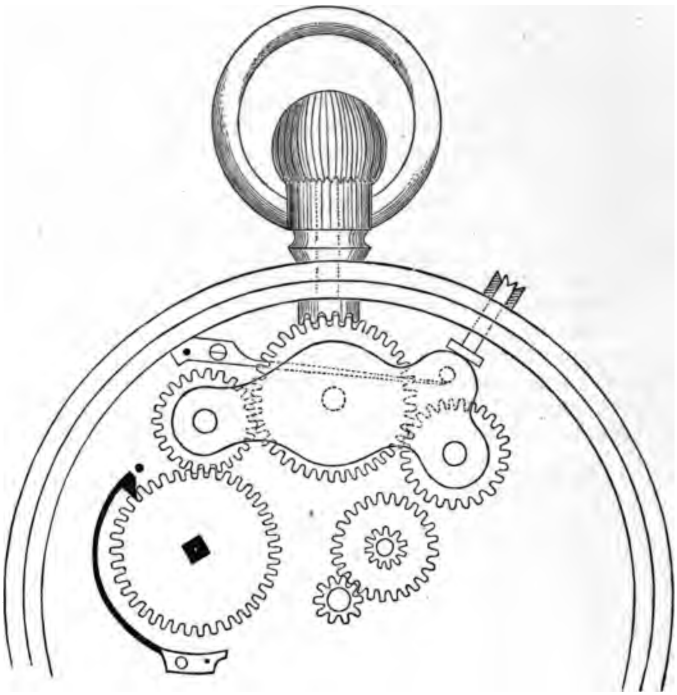


Fig. 29.

The balance of opinion is that a bevelled pinion working into a bevelled wheel does not answer so well as the contrate wheel arrangement shown in the drawing. With the bevelled pinion the strain in working tends to tilt the rocking bar. When the contrate wheel is used the teeth on the under side of the wheel with which it gears should be rounded. To ensure smooth working this outside wheel as it is called should not be exactly opposite to the pendant but a trifle to the left towards the barrel wheel. The smaller wheel running between this and the barrel wheel should be pitched rather shallow into both of the wheels with which it gears. There should be a stop to prevent it running too deep with the barrel wheel. This intermediate wheel is sure to get deeper with wear, and if full at first the winding is likely to become rough in consequence.

Shifting Sleeve Keyless Mechanism.

The usual form of keyless work used in Swiss watches is shown in Fig. 33 (page 77). A bevelled pinion with clutch teeth underneath rides loose on the stem of the winding button and gears with bevelled teeth on the face of the large wheel which is just below the pendant. The part of the winding stem below the bevelled pinion is square, and upon this part is fitted a sleeve with clutch teeth corresponding with those on the bevelled pinion at its upper extremity, and a contrate pinion at its lower extremity. A groove is formed around the sleeve in which is a spring pressing the sleeve upwards so as to keep the clutch teeth engaged. While the clutch teeth are so engaged the winding may be proceeded with. To set hands a push piece projecting through the band of the case acts on a knuckle of the spring just mentioned, so that as the push piece is pressed in the spring draws the sleeve away from the clutch teeth of the bevelled pinion and brings the contrate pinion into gear with a small wheel, which latter gears with the minute wheel.

The remarks on the depths, click, etc., in the description of the Rocking Bar Mechanism are equally applicable to this form. If a stiff click is used as shown in the figure it should be short, and planted so that the hole in the click, the point of the click, and the centre of the barrel are almost in a line. The click in the drawing would bear to be even a little shorter with advantage. A short click planted in this way permits a little recoil after the watch is tightly wound.

Fusee Keyless Work.

The simple keyless mechanism used for going barrels is not suitable for the fusee, because in the latter the main spring is wound by turning the fusee, and accidental pressure on the button would most likely stop the watch if the winding wheels were left in action after winding.

Fig, 30 shows a very clever arrangement of fusee keyless work by Mr. W. Chalfont. The large circle on the left represents the winding wheel on the fusee and the smaller circle to the right of it the minute wheel. A wheel and pinion gearing together are mounted on a platform as shown. The platform is screwed to the plate, but the hole through which the screw passes is slotted so that the platform is free to move horizontally for a limited distance. A spring fixed to the plate pressing on a pin in the platform pushes it to the right till it is stopped by a space between two teeth of the pinion coming into contact with a pin in the plate. This is the position shown in the drawing. If now, by means of the winding button the contrate wheel is turned to the right as in the act of winding, the wheel on the platform cannot turn because of the pin, which is between two teeth of the pinion. The platform is there-

Fusee Keyless Work.

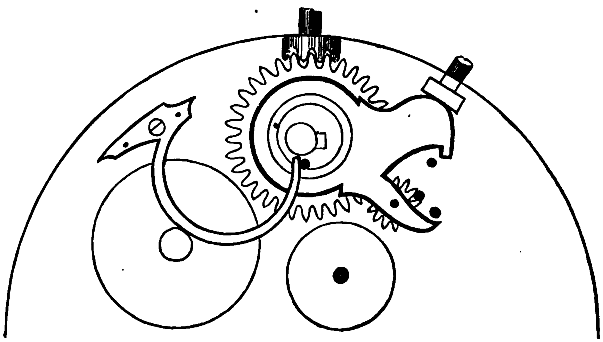


Fig. 30.

fore carried to the left and the wheel on the platform engages with the winding wheel on the fusee. By this time the pinion is drawn free of the pin, a projecting tail of the platform is caught by another pin in the plate, and the winding may be proceeded with. As the button is released the mechanism returns to the position shown in the drawing, and when the button is turned the reverse way the pinion trips over the little pin in the plate. This pin should be placed so that as the winding wheel on the platform is carried forward it presents the point of but one tooth to the fusee wheel. By this means butting as these two wheels go into gear is avoided. To set hands the push piece which passes through the band of the case presses the platform down, the pinion is carried free of the pin and into gear with the minute wheel. The wheel on the platform is kept free of the fusee wheel by another pin in the plate catching a hooked projection on the platform.

Self-Winding Watches.

Fig. 31 shows an arrangement of mechanism by M. Lebet for winding a watch by the action of closing the hunting cover. There is a short gold arm projecting beyond the joint. This arm is connected by means of a double link to a lever, one end of which is pivoted to the plate. To the free end of this lever is jointed a sythe shaped

Lebet's Winding Work.

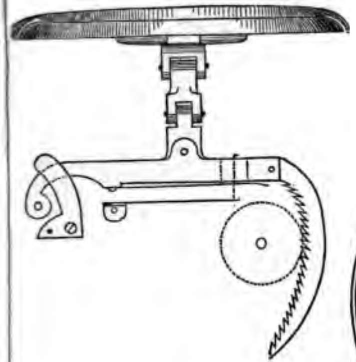


Fig. 31.

Loehr's Winding Work.

Fig. 32.

rack, which works into a wheel with ratchet shaped teeth on the barrel arbor. A weak spring fastened to the lever serves to keep the rack in contact with the wheel teeth. Instead of the ordinary fly spring there is a spring fixed to the plate and attached by means of a short chain to the lever. As this spring pulls the cover open the teeth of the rack slip over the teeth of the wheel on the barrel arbor. Each time the wearer closes the cover the watch is partly wound. By closing the case eight or nine times the winding is completed. The ordinary method of hooking in the main spring would be clearly unsuitable with this winding work, because after the watch was fully wound the case could not be closed. M. Lebet places inside the barrel a piece of main spring a little more than a complete coil with the ends overlapping, and to this piece the main spring hook is rivetted. The adhesion of the loose turn of main spring against the side of the barrel is sufficient to drive the watch, but when the hunting cover is closed after the watch is wound the extra strain causes the main spring to slip round in the barrel.

The method of winding just described can be applied only to a hunting watch. Fig. 32 represents an invention of Herr von Loehr, in which the motion of the wearer's body is utilized in winding. There is a weighted lever (G) pivotted at one end and kept in its normal position against the upper of two banking pins by a long curved spring so weak that the ordinary motion of the wearer's body causes the lever to continually oscillate between the banking pins. Pivotted to the same centre as the weighted lever is a ratchet wheel with very fine teeth, and fixed to the lever is a pawl (*a*) which engages with the ratchet wheel. This pawl is made elastic so as to yield to undue strain caused by the endeavour of the lever to vibrate after the watch is wound. A is the barrel arbor, and the connection between it and the ratchet wheel is made by a train of wheels as shown. *b* is a second pawl to prevent the return of the ratchet wheel. For setting hands there is a disc (B) which has a milled surface slightly cupped to suit the point of a finger.

The peculiar shaped bow is to ensure the watch remaining upright in the pocket.

Pedometer.—The drawing of Von Loehr's winding work (Fig. 32) conveys very fairly the principle of the pedometer used for registering the number of paces walked. In the case of the pedometer the pawl is rigid and the last wheel of the train is planted in the centre of the movement. The centre wheel arbor carries a hand which traverses a dial on the other side of the plate. Instead of the lower banking pin there is a screw to adjust the amount of travel of the lever, and therefore the number of teeth of the ratchet wheel pushed forward at each vibration, to suit the stride of the wearer. By this means the divisions on the dial are made to represent approximately the number of miles walked.

Centre Seconds Chronograph.

The chronograph hand is fixed to the pipe of a brass wheel which runs freely on the centre arbor under the canon pinion. This wheel has a finely serrated edge and is driven by a smaller wheel having its edge serrated in the same manner. This latter is

Centre Seconds Chronograph.

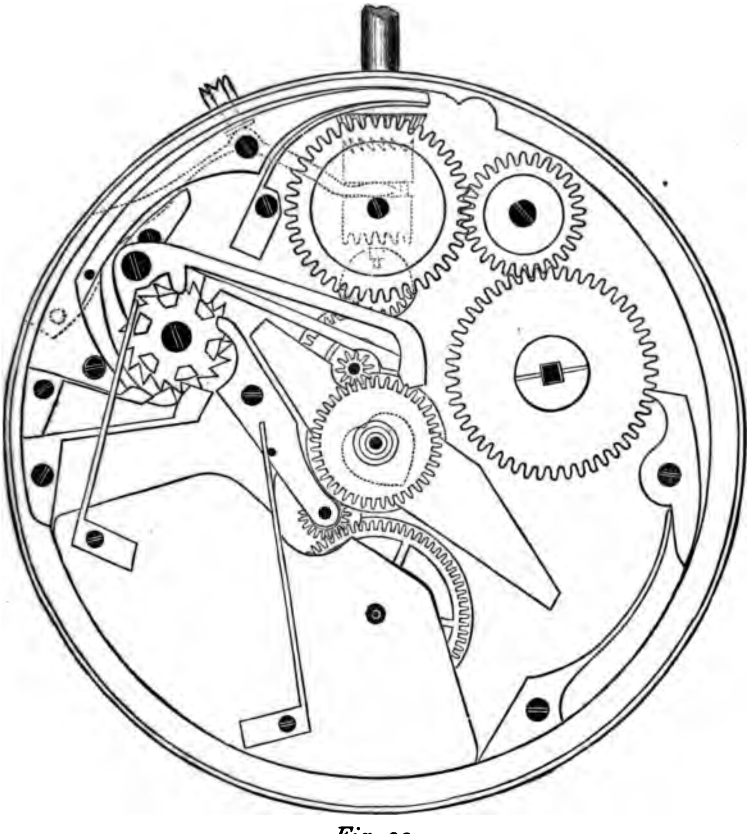


Fig. 33.

attached to a pinion which gears with the fourth wheel. The two serrated wheels bear the same proportion to each other as the fourth wheel does to the pinion already mentioned, so that the chronograph hand travels round the dial in a minute, which is the time that the fourth wheel takes to make a revolution. The smaller serrated wheel and the pinion to which it is attached are mounted on a pivotted carriage with a projecting tail. In Fig 33 the two serrated wheels are in contact and the chronograph hand is consequently travelling. If now the button in the pendant is pressed, the shorter end of the bent lever which is lying around inside the case, is depressed, and the hooked end of the lever draws the star wheel round so that the tail of the carriage on which the small serrated wheel is mounted is moved far enough to take it from contact with the larger wheel, and the chronograph hand consequently stops. At the same time a tooth of the star wheel which has been keeping a circular brake off the larger serrated wheel is moved out of the way so that the brake drops, thus keeping the chronograph hand from being shifted by accidental motion of the watch. When the button is again depressed the star wheel is shifted round still further, and the lever with the pointed end is allowed to drop on to the heart shaped cam, which is fixed to the larger of the serrated wheels. As the lever drops, its tail lifts the brake off the serrated wheel, and the weight of the lever, aided by a spring, as shown in the drawing, is sufficient to turn the cam from whatever position it may happen to be in till the lever rests on that part of the edge of the cam which is nearest to its centre of motion. The chronograph hand is then at zero.

Although the chronograph, on account of its ability to measure fractions of a second, has almost displaced the independent centre seconds watch, it is by no means a perfect construction. The serrated wheels are not calculated to withstand continuous wear, and it is evident that however fine the serrations they would cause the chronograph hand to jump backward or forward when brought into contact unless a serration and groove happen to exactly coincide. This is often aggravated by minute portions of a broken glass or other grit getting in the serrations.

If the smaller serrated wheel is removed and the hand brought to zero it should not move however often the button is pushed in, but it often occurs that if the spring pressing on the lever which falls on the heart shaped cam or on the brake lever is too strong and the lever itself rather weak the lever gives a little and causes the hand to shift. This is one of the most common faults met with, and may be rectified by weakening the spring or bringing it to bear more on the end of the lever farthest from its centre of motion. The same jerking of the hand is sometimes observed when the pivots of the levers do not accurately fit the holes.

Repeating Watches.

Repeaters were first made about 1676. The honour of the invention is claimed for Edward Barlow, a priest; Daniel Quare, and Tompion.

Fig. 34 is a very fair representation of half quarter repeating work copied from a movement lent to me by Messrs. Nicole & Co. Some of the parts are differently arranged by other makers, but the principle of all is the same.

Half-Quarter Repeating Work.

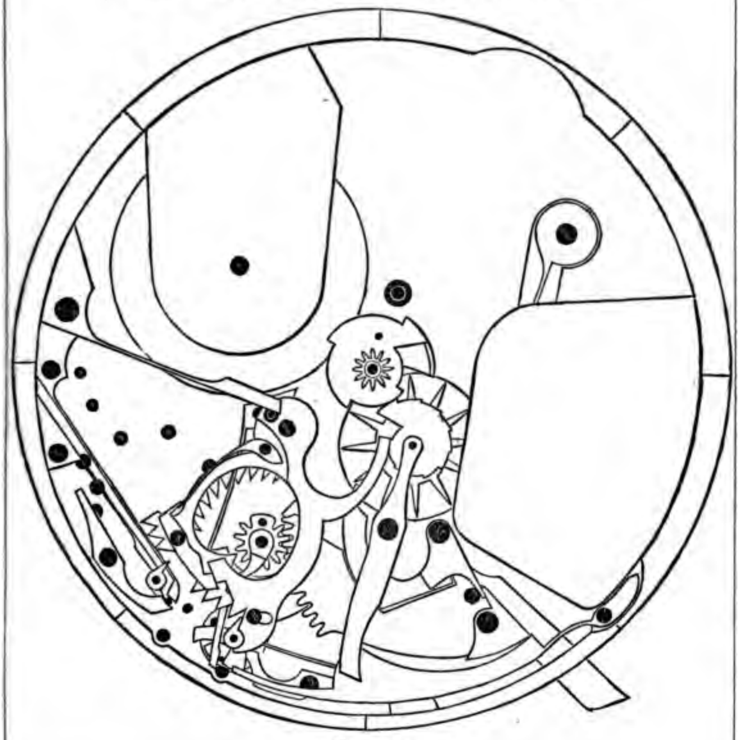


Fig. 34.

The small main spring which supplies the power for repeating is wound up by the wearer pushing round a slide that projects from the band of the case. This slide is the extremity of a lever which presses against a pivotted rack engaging with a segment on the barrel arbor. There is underneath a segment of greater radius containing twelve ratchet teeth. The number of hours to be struck is regulated by the position of the hour snail in precisely the same way as the striking work of a clock. At twelve o'clock the lowest step of the snail is presented to the stop so that the rack can be traversed its full extent. In returning each one of the twelve ratchet teeth in turn lifts the hammer that strikes the hours. The quarter rack has two sets of three ratchet teeth each, and as the slide is moved round the all-or-nothing-piece, as it is called, releases the quarter rack, against which a spring is constantly pressing. The quarter rack is stopped by the quarter snail. After the hours are struck a curved finger, or gathering pallet, on the barrel arbor presses the quarter rack to its original position, and in passing each of the ratchet teeth, by pushing aside a pallet fixed to the same arbor as the hammer, strikes a blow. Whether one, two, or three-quarters are struck depends, of course, on the position of the quarter snail.

The half quarter rack, with but one ratchet tooth, is placed on top and works with the quarter rack. Between each quarter and seven minutes past it yields as it passes the lifting pallet.

The quarter snail attached to the canon pinion is doubled, with steps just dividing each other, so that after the half quarter the quarter rack gets round a little nearer to the centre of the snail than the half quarter rack. This allows the spring catch, which is mounted on the quarter rack, to lock the half quarter rack, and then, after the quarters have struck, it lifts the hammer and strikes one more blow.

The hour snail is mounted on a star wheel, as shown, and the star wheel is moved by a pin in the quarter snail, or rather in the loose surprise piece underneath, which flies out to the position shown in the drawing directly the star wheel is moved. The surprise then prevents the quarter rack reaching any step of the quarter snail, and consequently no quarters are struck. When the pin in the surprise piece come round to the star wheel again the pressure of the pin on a tooth of the star wheel causes the surprise piece to retire so that the third quarter and half quarter can be struck, but as the star wheel jumps forward the succeeding tooth flicks out the surprise.

The hammer arbors go through the plate and the hammers are on the other side.

There is also on the other side of the plate a train of runners for regulating the speed of striking. The centres of the wheels are indicated by dots on the left hand of the barrel. The last pinion is not furnished with a fly as in clocks, but there is a screw with an eccentric head by means of which the depth of the last pinion can be increased or made shallower. This is found to be sufficient regulation.

On Pendulums.

The theoretical length in London of a seconds pendulum for mean solar time—that is the distance between the point of suspension and the centre of oscillation,* is approximately 39·14 inches; the length of pendulum for vibrating sidereal seconds in the same latitude is 38·87 inches.

The length of the seconds pendulum varies in different latitudes. It is 39 inches at the Equator and 39·206 inches at the Poles.

At Rio Janeiro	it is	39·01	inches.
At Madras	,,	39·02	,,
At New York	,,	39·10	,,
At Paris	,,	39·13	,,
At Edinburgh	,,	39·15	,,
At Greenland	,,	39·20	,,

The following is one of the simplest rules for ascertaining the length of a pendulum for a given number of vibrations, accepting the seconds pendulum of 39·14 inches as a datum :—

Let V = the given number of vibrations per minute.
Let L = the length required in inches.

Then $L = \overline{375{\cdot}4 \div V}^2$

Example.—The length is required of a pendulum to give 120 vibrations a minute.

375·4 ÷ 120 = 3·128 and 3·128 squared = 9·78, the length required.

If the length of a pendulum is given, the number of vibrations it would make in a minute may be ascertained as follows :—

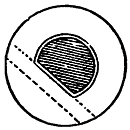
Let L = the length given in inches.
Let V = the number of vibrations per minute.
Then $V = 375{\cdot}4 \div \sqrt{L}$.

NOTE.—For obtaining the square root of a number see Table at page 87. Table of lengths of pendulums on page 90. Table of weights of hollow cylinders of iron, lead, and zinc on page 88.

* The centre of oscillation is that point in a vibrating body in which if all the matter composing the body were collected into it the time of the vibrations would not be affected. In a straight bar suspended at one extremity the centre of oscillation is at two thirds of its length, and in a long cone suspended at the ape at four-fifths of its length from the apex. From the irregular form of the pendulum the position of its centre of oscillation is not easy to calculate, but it is always situated below the centre of gravity or centre of mass of the bob.

Zinc and Steel Compensation.—Fig. 35 shows the construction of a zinc and steel compensation pendulum, similar in principle to those employed in the Westminster clock and in the Standard Sidereal clock at Greenwich. For a seconds pendulum on this plan the rod of steel should be ·3-inch diameter and 45 inches long from the top of the free part of the suspension spring to the bottom of the rod; with a screw of 40 threads to the inch for a length of four inches from the bottom to receive the rating nut. On the upper end a cap is screwed with a pin right through for safety. The upper part of the cap is slit to receive the suspension spring.

A trebly drawn zinc tube, just large enough to slip easily over the rod, ·2 inch thick and 25 inches long should be provided. This is the length generally used and it is also correct according to the relative expansion of zinc and steel as given in the Table at page 89; still it would be prudent to start with the tube rather long; it can be easily shortened after trial. Indeed it should be left rather long, for with a heavy bob resting in a zinc tube the tube in course of years shortens perceptibly. The Westminster clock has been kept to mean time by adding small weights to the pendulum above the bob; such a number of these weights accumulated that it was found desirable to cast one large one instead. It was, I believe, concluded that the zinc tube had shortened and so lowered the bob.



This tube rests on a thick washer or collar just above the rating nut. The surface of the collar and end of the tube may be quite square. The grooving sometimes adopted is not necessary if the tube is the proper size in the bore. But provision should be made to prevent the collar turning with the rating nut. The simplest way is to file the pendulum rod flat for about five inches up and to put a pin through the collar just free of the flat part of the rod as in the appended sketch.

Outside the zinc tube slipping freely over it is a thin iron tube about 22 inches long. Holes are made at intervals in this tube to allow the air to get freely in contact with the zinc tube. These holes should not be round; they give a mean appearance to the pendulum, which goes far to account for the dislike with which these pendulums are viewed by many. Slots with semi circular ends look very well and are not much trouble to make. Two ·2-inch holes are drilled ·5 inch apart right through the tube and the intervening piece of metal cut away, or the slots may be cut in one operation with a milling tool revolving in the lathe chuck and the tube held in the slide rest and traversed to and fro. A collar with a hole in the middle, of a size to slip freely over the steel rod, and ·25-inch thick, should be brazed inside of the upper end of the iron tube. A collar about ·35-inch thick is either brazed, which is best, or screwed to the outside of the lower end of the iron tube.

Zinc and Steel Compensation Pendulums.

Fig. 35.

Fig. 36.

The bob is of lead, 3 inches in diameter and 9 inches long. The upper part of the hole just passes over the iron tube. Half way up from the bottom the hole is enlarged so as to pass over the collar on the outside of the iron tube. By this means a seat is provided in the middle of the bob for it to rest on the collar.

The suspension spring is usually about ·5 in. wide, ·008 in. thick, and the free part from 1·5 to 2 inches long.

Another Form of Zinc and Steel Compensation.—Many people object to the pendulum just described as being unsightly. The outer tube looks rough unless it is turned, and brazing the upper collar, which is the neatest and most satisfactory way of fixing it, is found to be difficult.

Fig. 36 shows two steel side rods substituted for the outer iron tube; in other respects the pendulum is constructed like Fig. 35.

The side rods are ·3 in diameter, the same as the central rod, and at the top a cap as shewn. At their lower ends there is a collar fitting loosely round the zinc tube and on this collar the bob rests.

An old clock of Reid's, with a pendulum constructed substantially like Fig. 36, has been under my daily observation for the last ten years, and I am enabled to say that the compensation is perfect. There is no perceptible difference in its error during summer and winter. The zinc tube is coated with black varnish and the pendulum altogether has, I think, a nicer appearance than those with the outer iron tube. The opinion prevails among clockmakers that zinc gradually loses its power of expansion, but this appears to be quite unwarranted; the notion probably arose from observing that zinc tubes when supporting a heavy weight shorten in time, which has been referred to above.

Mercurial Compensation.—In the mercurial pendulum the jar of mercury does not answer so quickly to a change of temperature as the steel rod, and preference is therefore now generally given to the zinc and steel arrangements; still the elegant appearance of the mercurial renders it suitable for show regulators, for which it is often used. The following are the dimensions of a good pendulum of this class:—Steel rod ·3 inch diameter, 34 inches long from top of free part of suspension spring to bottom of sole of stirrup, side rods of stirrup ·3 inch wide and ·125 inch thick, height of stirrup inside 8 inches, bottom of stirrup ·5 inch thick with a recess turned out to receive the jar; glass jar 7·6 inches deep and 2 inches diameter inside, outside 2·25 diameter, and 7·8 inches high; height of mercury in the jar about 4.7 inches; the weight of mercury was 11lbs. 12oz.

Wood Rod and Lead Bob.—A cheap and good compensated pendulum may be made with a wood rod and lead bob.

For a seconds pendulum the rod should be of thoroughly well seasoned straight grained deal 44·5 inches long, measuring from the top of the free part of the suspension spring to the bottom of the bob, and of an oval section ·75 inch by ·5 inch. This size of rod allows of sound fixing for the attachments at the ends. A slit for the suspension spring is cut in a brass cap fitting over the top of the rod, to which it is secured by two pins. A bit of thin brass tube is fitted to the rod where it is embraced by the crutch. The rating screw, ·25 inch in diameter, is fixed to a short piece of sheet brass ·75 of an inch wide. A saw cut is made at the bottom of the pendulum rod, into which the brass plate is inserted and fixed with a couple of pins. Wooden rods require to be coated with something to render them impervious to the atmosphere. They are generally varnished or polished, but painting them answers the purpose well.

The bob 2·25 inches diameter and 11 inches high, with a hole just large enough to go freely over the wood rod, rests on a washer above the rating nut.

Many pendulums made on this plan have been all that could be desired. Several correspondents have borne testimony to their efficiency, but nearly all have told me that the bob 14 inches high as prescribed in former editions of the Hand Book is too long for a seconds pendulum. A length of 12, 11, 10 and even 8 inches is advised. I have taken 11 inches really as a mean. Doubtless there is not the certainty in the ratio of expansion of wood that there is in metal.

Shorter pendulums for chime and other clocks are made of teak, mahogany and ebony, simply because in such small sizes deal does not allow of sound attachment to the ends. These pendulums have generally lenticular shaped bobs. Such rods cost scarcely any more than brass or iron and are infinitely preferable.

Importance of Fixing.—Whatever kind of pendulum is used it will not keep time unless it is rigidly fixed. Just as engineer clockmakers invariably make their escape wheels and other moving parts too heavy so clockmakers always seem afraid to put enough metal in their pendulum cocks and brackets which have rarely enough base either. The beneficial effect of the heavy pendulum bobs, which it has been the custom recently to use for regulator and turret clocks, is often quite lost for want of sufficient fixing for the pendulum. The back of a regulator case should be 1·5 inch thick, and the pendulum supported on a cast iron bracket with a base 10 or 12 inches square bolted right through the back of the case. For a turret clock a bracket of a proportional size should be used bolted to one of the main walls of the building if possible. A timber frame fixing for a turret clock pendulum will never be satisfactory.

Length of Pendulums.—One second pendulums are long enough for all but large turret clocks, and longer than two second pendulums should not be used. The very long pendulums used by the old clockmakers for turret clocks in order to get, as they expressed it, "a dominion over the clock," were very unwieldy and unsteady from the action of the wind and other causes. The requisite "dominion" is now obtained by making the bob heavier.

Pendulum Error.—The long and short vibrations of a free pendulum will only be isochronous if the path described is a cycloid, which is a curve described by rolling a circle along a straight line. If you look at Fig. 2 you will see there represented the method of describing a epicycloid for wheel teeth, which is done by rolling one circle on another. If the generating circle instead of being rolled on another circle were rolled along a straight edge it would describe a cycloid. But a pendulum swung freely from a point travels through a circular path and the long arcs are performed slower than the short ones. This divergence from the theoretical cycloid was of great importance when the arc described was large, as it was of necessity with the verge escapement, and many devices were tried to lead the pendulum through a cycloid. With an arc of about 3° only such as regulator pendulums describe now the divergence is very small.

Escapement Error.—The kind of escapement used also affects the time of vibration; for instance, it is found that, while with the recoil escapement increased motive power and greater arc causes the clock to gain, the contrary effect is produced with the dead beat escapement. The pendulum error may therefore be aggravated or neutralized by the escapement error.

Temperature Error.—With increase of temperature the pendulum, in common with most other substances, lengthens, and the clock loses; with decrease of temperature the contrary effect is produced. The object of the compensation pendulum is to meet the error arising from change of temperature by keeping the distance between the point of suspension and the centre of oscillation constant.

Barometric Error.—With a decrease in the pressure of the air and consequent fall of the barometer the pendulum increases its arc of vibration; with an increase in the pressure of the air and consequent rise of the barometer the pendulum diminishes its arc of vibration. In the Westminster clock the pendulum vibrates $2{\cdot}75^\circ$ on each side of zero, and Sir Edmund Beckett points out that with this large arc the circular error just compensates for the barometic error. Where the escapement is suitable this is doubtless the best way of neutralizing the barometric error, but it is not applicable to the dead beat for extra run on the dead faces of the pallets or larger angle of impulse than usual is found to be detrimental, as the oil thickens.

Square Roots of Numbers from 1 to 200.

To Extract Root of Whole Number and Decimal Part *see page 88.*

No.	*Square Roots.*	*No.*	*Square Roots.*	*No.*	*Square Roots.*	*No.*	*Square Roots.*
1	1·0000	51	7·1414	101	10·0498	151	12·2882
2	1·4142	52	7·2111	102	10·0995	152	12·3288
3	1·7320	53	7·2801	103	10·1488	153	12·3693
4	2·0000	54	7·3484	104	10·1980	154	12·4096
5	2·2360	55	7·4161	105	10·2469	155	12·4498
6	2·4494	56	7·4833	106	10·2956	156	12·4899
7	2·6457	57	7·5498	107	10·3440	157	12·5299
8	2·8284	58	7·6157	108	10·3923	158	12·5698
9	3·0000	59	7·6811	109	10·4403	159	12·6095
10	3·1622	60	7·7459	110	10·4880	160	12·6491
11	3·3166	61	7·8102	111	10·5356	161	12·6885
12	3·4641	62	7·8740	112	10·5830	162	12·7279
13	3·6055	63	7·9372	113	10·6301	163	12·7671
14	3·7416	64	8·0000	114	10·6770	164	12·8062
15	3·8729	65	8·0622	115	10·7238	165	12·8452
16	4·0000	66	8·1240	116	10·7703	166	12·8840
17	4·1231	67	8·1853	117	10·8166	167	12·9228
18	4·2426	68	8·2462	118	10·8627	168	12·9614
19	4·3588	69	8·3066	119	10·9087	169	13·0000
20	4·4721	70	8·3666	120	10·9544	170	13·0384
21	4·5825	71	8·4261	121	11·0000	171	13·0766
22	4·6904	72	8·4852	122	11·0453	172	13·1148
23	4·7958	73	8·5440	123	11·0905	173	13·1529
24	4·8989	74	8·6023	124	11·1355	174	13·1909
25	5·0000	75	8·6602	125	11·1803	175	13·2287
26	5·0990	76	8·7177	126	11·2249	176	13·2664
27	5·1961	77	8·7749	127	11·2694	177	13·3041
28	5·2915	78	8·8317	128	11·3137	178	13·3416
29	5·3851	79	8·8881	129	11·3578	179	13·3790
30	5·4772	80	8·9442	130	11·4017	180	13·4164
31	5·5677	81	9·0000	131	11·4455	181	13·4536
32	5·6568	82	9·0553	132	11·4891	182	13·4907
33	5·7445	83	9·1104	133	11·5325	183	13·5277
34	5·8309	84	9·1651	134	11·5758	184	13·5646
35	5·9160	85	9·2195	135	11·6189	185	13·6014
36	6·0000	86	9·2736	136	11·6619	186	13·6381
37	6·0827	87	9·3273	137	11·7046	187	13·6747
38	6·1644	88	9·3808	138	11·7473	188	13·7113
39	6·2449	89	9·4339	139	11·7898	189	13·7477
40	6·3245	90	9·4868	140	11·8321	190	13·7840
41	6·4031	91	9·5393	141	11·8743	191	13·8202
42	6·4807	92	9·5916	142	11·9163	192	13·8564
43	6·5574	93	9·6436	143	11·9582	193	13·8924
44	6·6332	94	9·6953	144	12·0000	194	13·9283
45	6·7082	95	9·7467	145	12·0415	195	13·9642
46	6·7823	96	9·7979	146	12·0830	196	14·0000
47	6·8556	97	9·8488	147	12·1243	197	14·0356
48	6·9282	98	9·8994	148	12·1655	198	14·0712
49	7·0000	99	9·9498	149	12·2065	199	14·1067
50	7·0710	100	10·0000	150	12·2474	200	14·142

To Extract Root of Whole Number and Decimal Part.

If it is desired to extract the root of a whole number and decimal parts, multiply the difference between the root of the whole number and the next higher number in the preceding table by the decimal part of the given number and add the product to the root of the whole number given; the sum will be the root required, correct at all events to three places of decimals.

EXAMPLE.—Required the square root of 60·2.

$$\sqrt{61} = 7{\cdot}8102$$
$$\sqrt{60} = 7{\cdot}7459$$

$$\cdot0643 \times \cdot2 = \cdot01286.$$

And $7{\cdot}7459 + \cdot01286 = 7{\cdot}75876$ the root required.

Weight of Lead, Zinc, and Cast-Iron Cylinders One Inch Long.

DIAMETER IN INCHES.	WEIGHT IN POUNDS.			DIAMETER IN INCHES.	WEIGHT IN POUNDS.		
	LEAD.	ZINC.	IRON.		LEAD.	ZINC.	IRON.
·25	·020	·012	·012	3·25	3·400	2·098	2·156
·5	·080	·049	·050	3·5	3·944	2·434	2·491
·75	·180	·111	·114	3·75	4·51	2·783	2·865
1	·321	·198	·204	4	5·149	3·177	3·265
1·25	·503	·310	·319	4·25	5·813	3·587	3·686
1·5	·724	·447	·459	4·5	6·519	3·922	4·134
1·75	·984	·607	·624	4·75	7·265	4·483	4·607
2	1·287	·794	·816	5	8·048	4·966	5·103
2·25	1·630	1·005	1·033	5·25	8·872	5·474	5·626
2·5	2·009	1·239	1·274	5·5	9·737	6·008	6·175
2·75	2·434	1·502	1·544	5·75	10·643	6·567	6·749
3	2·897	1·788	1·837	6	11·590	7·152	7·350

The above table will be found useful for readily ascertaining the weight of cylinders for pendulum bobs and clock weights. Example :—Required, the weight of a lead pendulum bob 3 inches diameter 9 inches long, which has a hole through it ·75 inch in diameter. The weight of a lead cylinder 3 inches diar. in the table is 2·897, which multiplied by 9 (the length given) = 26·07 lbs. Then the weight in the table of a cylinder ·75 inch diameter is ·18 and ·18 × 9 = 1·62. And 26·07 — 1·62 = 24·45 the weight required in lbs.

Properties of Metals and other Substances.

DESCRIPTION.	*Weight of a cubic inch in lbs*	*Specific Gravity.* *	*Tenacity in lbs. per square inch.*	*Crushing force in lbs per square inch.*	*Melting point, Fahr.*	*Expansion between 32° & 212°.* ¶	*Conducting power.* †	*Specific heat*
Aluminium	·092	2·56	...	...	1800°	...	...	..
Ditto Bronze (90 per cent. copper)	·276	7·68	..	...	...	...	...	...
Antimony, cast ...	·242	6·7	1,066	...	810°	·0011	..	·0507
Bismuth	·35	9·82	3,250	...	497°	·0014	...	·0288
Brass, cast	·3	8·4	17,978	10,300	1800°	·002	...	...
Ditto, wire	...	8·5	49,000	...	...	...	...	...
Copper, cast	·32	8·89	19,072	11,700	1996°	·0017	...	·0449
Ditto, sheet	...	8·95	33,000	...	..	...	898	...
Ditto, wire	...	9·	61,000	...	..	...	...	...
Dry Deal Rod ...	·025	·68	..	...	...	·0008	...	...
Do. Ebony do. ...	·043	1·18	...	...	...	...	...	...
Gold pure, hammered	·7	19·35	20,400	...	2616°	·0016	1000	·0298
Ditto, cast	...	19·25	...	...	...	...	...	...
§Ditto, standard ...	·638	17·724	...	...	...	...	...	...
Gun Metal	·3	8·4	36,000	...	...	...	...	...
Glass	·1	2·83	...	...	...	·00082	...	...
‖Iron, wrought ...	·28	7·7	60,000	38,000	...	·0012	347	·1100
Ditto, cast	·26	7·18	19,000	92,000	2786°	·0011	...	...
Lead, cast	·41	11·35	1,824	7,000	612°	·0028	180	·0293
Ditto, sheet	..	...	3,328	...	...	...	...	...
Mercury	·49	13·59	...	...	39°	·018	...	·0333
Nickel	·31	8·82	...	...	...	...	...	...
Palladium	...	12	...	...	...	·001	...	...
Platinum	7·8	21·4	.	...	3080°	·00085	...	...
Silver, pure	38	10·47	41,000	...	1873°	·0019	973	·0557
‡Ditto, standard ...	·371	10·312	...	...	...	...	...	...
Steel	·282	7·82	120,000	...	...	·0011	...	...
Teak	·03	·86	...	...	...	...	...	...
Tin	·263	7·29	5,000	15,000	442°	·0021	304	·0514
Water (distilled 50°)	·036	1·00	...	...	32°	·0477	...	1·00
Zinc...	·253	7·	8,000	...	773°	·0027	363	·0927

* The specific gravity of a body is the proportion which its weight bears to the weight of an equal bulk of water.

† Gold 1000 is taken as the standard.

‖ Iron wire has a greater tenacity than wrought bar and may be taken as 85,000 lbs. per square inch.

¶ The figures given represent the proportion of its length which the substance expands to the range of temperature mentioned, except in the case of Mercury, in which the increase of volume is taken. In practice allowance must in the case of Mercury be made for the expansion of the containing vessel. In a glass pendulum jar Mercury may be taken to expand in length 5·8 times as much as the steel rod.

§ Gold is alloyed with silver or copper. Standard, or 22 carat gold, contains 22 parts of gold and 2 parts of alloy.

‡ Silver is alloyed with copper. 12ozs. Troy standard silver contains 11ozs. 10dwts. of pure silver.

Clock Trains and Lengths of Pendulums.

Wheels.	Pinions.	Escape Wheel.	Vibrations of Pendulum ℔ Min.	Length of Pendulum in Inches.	Wheels.	Pinions.	Escape Wheel.	Vibrations of Pendulum ℔ Min.	Length of Pendulum in Inches.
120 90 75	10 10 9	Double 3-Leg-ged.	*30	156·56	96 76	8	30	114	10·82
					115 100	10	30	115	10·65
120 90 90	10 9 9	Do.	*40	88·07	84 78	7	26	115·9	10 43
128 120	16	30	60	39·14	96 80	8	30	120	9·78
112 105	14	30	60	39·14	84 70	7	30	120	9·78
96 90	12	30	60	39.14	84 78	7	27	120·3	9·73
80 75	10	30	60	39.14	90 84	8	31	122	9·46
64 60	8	30	60	39·14	84 78	7	28	124·8	9·02
64 64	8	30	68	30·49	100 80	8	30	125	9·01
70 64	8	30	70	28·75	90 84	8	32	126	8·87
72 64	8	30	72	27·17	100 96	10	40	128	8·59
75 60	8	32	75	25·53	84 78	7	29	129·3	8·42
72 65	8	32	78	23·15	100 78	8	32	130	8·34
75 64	8	32	80	22·01	84 77	7	30.	132	8·08
84 64	8	30	84	19·97	84 78	7	30	133·7	7·9
86 64	8	30	86	19·06	90 90	8	32	135	7·68
88 64	8	30	88	18·19	84 78	7	31	138·2	7·15
84 78	7	20	89·1	17·72	84 80	8	40	140	7·18
80 72	8	30	90	17·39	120 71	8	32	142	6·92
84 78	7	21	93·6	16·08	84 78	7	32	142·6	6·9
94 64	8	30	94	15·94	100 87	8	32	145	6·69
84 78	8	28	95·2	15·52	84 78	7	33	147·1	6·5
108 100	12 & 10	32	96	15·28	100 96	8	30	150	6·26
84 84	9 & 8	30	98	14·66	84 78	7	34	151·6	6·1
84 78	7	22	98	14·66	96 95	8	32	152	6·09
84 78	8	29	98.6	13·44	84 77	7	35	154	5·94
80 80	8	30	100	14·09	104 96	8	30	156	5·78
83 72	8	32	102	13·54	84 78	7	35	156	5·78
84 78	8	30	102	13·54	120 96	9 & 8	30	160	5·5
84 78	7	23	102·5	13.4	84 78	7	36	160.	5·5
105 100	10	30	105	12·88	84 78	7	37	164·9	5·15
84 78	8	31	105·4	12·67	132 100	9 & 8	27	165	5·17
84 78	7	24	107	12·3	84 78	7	38	169·4	4·88
96 72	8	30	108	12·14	128 102	8	25	170	4·87
84 78	8	32	108·8	11·9	84 78	7	39	173·8	4·65
88 80	8	30	110	11·64	36 36 35	6	25	175	4·6
84 77	7	25	110	11·64	84 77	7	40	176	4·5
84 78	7	25	111·4	11·29	84 78	7	40	178·3	4·3
84 80	8	32	112	11·22	45 36 36	6	20	180	4·25
84 78	8	33	112·2	11·15	47 36 36	6	20	188	3·92

* These are good examples of turret clock trains ; the great wheel (120 teeth) makes in both instances a revolution in three hours. From this wheel the hands are to be driven. This may be done by means of a pinion of 40 gearing with the great wheel, or a pair of bevel wheels bearing the same proportion to each other (three to one) may be used, the larger one being fixed to the great wheel arbor. The arrangement would in each case depend upon the number and position of the dials. The double three-legged gravity escape wheel moves through 60° at each beat, and therefore to apply the rule given for calculating clock trains it must be treated as in an escape wheel of three teeth. The barrel should be of iron cast hollow ; its diameter and length would be determined by the amount of fall to be obtained. Steel wire rope should be used for the attachment of the driving weights, and the larger the barrel is in reason the better, for with a very small barrel there is danger of crippling the wire ropes.

Circumferences and Areas of Circles advancing by Tenths.

The circumference of a circle = diameter × 3·14159. (π is used by mathematicians to represent 3·14159.)
The area of a circle = the square of the diameter × ·7854.
The diameter of a circle × ·886226 = the side of an equal square.
The diameter of a circle × ·7071 = the side of an inscribed square.
An arc of 57·29578° = the radius.

Diam.	*Circum.*	*Area.*	*Diam.*	*Circum.*	*Area.*
1	3·1416	·7854	5	15·7080	19·6350
·1	3·4557	·9503	·1	16·0221	20·4282
·2	3·7699	1·1309	·2	16·3363	21·2372
·3	4·0840	1·3273	·3	16·6504	22·0618
·4	4·3982	1·5393	·4	16·9646	22·9022
·5	4·7124	1·7671	·5	17·2788	23·7583
·6	5·0265	2·0106	·6	17·5929	24·6301
·7	5·3407	2·2698	·7	17·9071	25·5176
·8	5·6548	2·5446	·8	18·2212	26·4208
·9	5·9690	2·8352	·9	18·5354	27·3397
2	6·2832	3·1416	6	18·8496	28·2744
·1	6·5973	3·4636	·1	19·1637	29·2247
·2	6·9115	3·8013	·2	19·4779	30·1907
·3	7·2256	4·1547	·3	19·7920	31·1725
·4	7·5398	4·5239	·4	20·1062	32·1699
·5	7·8540	4·9087	·5	20·4204	33·1831
·6	8·1681	5·3093	·6	20·7345	34·2120
·7	8·4823	5·7255	·7	21·0487	35·2566
·8	8·7964	6·1575	·8	21·3628	36·3168
·9	9·1106	6·6052	·9	21·6770	37·3928
3	9·4248	7·0686	7	21·9912	38·4846
·1	9·7389	7·5476	·1	22·3053	39·5920
·2	10·0531	8·0424	·2	22·6195	40·7151
·3	10·3672	8·5530	·3	22·9336	41·8539
·4	10·6814	9·0792	·4	23·2478	43·0085
·5	10·9956	9·6211	·5	23·5620	44·1787
·6	11·3097	10·1787	·6	23·8761	45·3647
·7	11·6239	10·7521	·7	24·1903	46·5663
·8	11·9380	11·3411	·8	24·5044	47·7837
·9	12·2522	11·9459	·9	24·8186	49·0168
4	12·5664	12·5664	8	25·1328	50·2656
·1	12·8805	13·2025	·1	25·4469	51·5306
·2	13·1947	13·8544	·2	25·7611	52·8102
·3	13·5088	14·5220	·3	26·0752	54·1062
·4	13·8230	15·2053	·4	26·3894	55·4178
·5	14·1372	15·9043	·5	26·7036	56·7451
·6	14·4513	16·6190	·6	27·0177	58·0881
·7	14·7655	17·3494	·7	27·3319	59·4469
·8	15·0796	18·0956	·8	27·6460	60·8213
·9	15·3938	18·8574	·9	27·9602	62·2115

Diam.	Circum.	Area.
9	28·2744	63·6174
·1	28·5885	65·0389
·2	28·9027	66·4762
·3	29·2168	67·9292
·4	29·5310	69·3979
·5	29·8452	70·8823
·6	30·1593	72·3824
·7	30·4735	73·8982
·8	30·7876	75·4298
·9	31·1018	76·9770
10	31·4160	78·5400
·1	31·7301	80·1186
·2	32·0443	81·7130
·3	32·3580	83·3230
·4	32·6726	84·9488
·5	32·9868	86·5903
·6	33·3009	88·2475
·7	33·6151	89·9204
·8	33·9292	91·6090
·9	34·2434	93·3133
11	34·5576	95·0334
·1	34·8717	96·7691
·2	35·1859	98·5205
·3	35·5010	100·2877
·4	35·8142	102·0705
·5	36·1284	103·8691
·6	36·4425	105·6834
·7	36·7567	107·5134
·8	37·0708	109·3590
·9	37·3840	111·2204
12	37·6992	113·0976
·1	38·0133	114·9904
·2	38·3275	116·8989
·3	38·6416	118·8231
·4	38·9558	120·7631
·5	39·2700	122·7187
·6	39·5841	124·6901
·7	39·8983	126·6771
·8	40·2124	128·6799
·9	40·5266	130·6984
13	40·8408	132·7326
·1	41·1549	134·7824
·2	41·4691	136·8480
·3	41·7832	138·9294
·4	42·0974	141·0264
·5	42·4116	143·1391
·6	42·7257	145·2675
·7	43·0399	147·4117
·8	43·3540	149·5715
·9	43·6682	151·7471
14	43·9824	153·9384
·1	44·2965	156·1453
·2	44·6107	158·3680
·3	44·9248	160·6064
·4	45·2390	162·8605
·5	45·5532	165·1303
·6	45·8673	167·4158
·7	46·1815	169·7170
·8	46·4956	172·0340
·9	46·8098	174·3666
15	47·1240	176·7150
·1	47·4381	179·0790
·2	47·7523	181·4588
·3	48·0664	183·8542
·4	48·3806	186·2654
·5	48·6948	188·6923
·6	49·0089	191·1349
·7	49·3231	193·5932
·8	49·6372	196·0672
·9	49·9514	198·5569
16	50·2656	201·0624
·1	50·5797	203·5835
·2	50·8939	206·1203
·3	51·2080	208·6729
·4	51·5224	211·2411
·5	51·8364	213·8251
·6	52·1505	216·4248
·7	52·4647	219·0402
·8	52·7788	221·6712
·9	53·0930	224·3180
17	53·4072	226·9806
·1	53·7213	229·6588
·2	54·0355	232·3527
·3	54·3496	235·0623
·4	54·6038	237·7877
·5	54·9780	240·5287
·6	55·2921	243·2855
·7	55·6063	246·0579
·8	55·9204	248·8461
·9	56·2346	251·6500
18	56·5488	254·4696
·1	56·8629	257·3048
·2	57·1771	260·1558
·3	57·4912	263·0226
·4	57·8054	265·9050
·5	58·1196	268·8031
·6	58·4337	271·7169
·7	58·7479	274·6465
·8	59·0620	277·5917
·9	59·3762	280·5527
19	59·6904	283·5294
·1	60·0045	286·5217
·2	60·3187	289·5298
·3	60·6328	292·5536
·4	60·9470	295·5931
·5	61·2612	298·6483
·6	61·5753	301·7192
·7	61·8895	304·8060
·8	62·2036	307·9082
·9	62·5178	311·0252
20	62·8320	314·1600

The Dead Beat or "Graham" Escapement.

(Invented by George Graham at the beginning of the Eighteenth Century.)

For regulators and other clocks with seconds pendulum this escapement, which is shown in Fig. 37, is the one most generally approved. The only defect inherent in its construction is that the thickening of the oil on the pallets will affect the rate of the clock after it has been going some time. Notwithstanding this it has held its own against all other escapements on account of its simplicity and certainty of action. The pallets of the Graham escapement were formerly made to embrace fifteen teeth of the wheel, and until recently ten, but now many escapements are made as shown in the drawing with the pallets embracing but eight. This reduces the length of the impulse plane and the length of run on the dead face for a given arc of vibration and consequently the relative effect of the thickening of the oil. The angle of impulse is kept small for the same reason. There is not much gained by making the pallets embrace a less number of teeth than eight, for the shake in the pivot holes and inaccuracies of work cannot be reduced in the same ratio and are therefore greater in proportion. This involves larger angles and more drop. It is purely a practical question and has been decided by the adoption of eight teeth as a good mean. Escaping over eight teeth too gives a ready rule for the dimensions of pallet arms and position of pallet staff hole, as will be explained.

To Set Out the Escapement.—Draw a circle representing the escape wheel to any convenient size and, assuming the wheel to have 30 teeth and the pallets are to embrace eight of them, set off on each side of a centre line by means of a protractor 45°. Lines drawn from the centre of the escape wheel through these points will pass through the centre of the impulse faces of the pallets; thus, 360 (number of degrees in the whole circle), divided by 30 (proposed number of teeth) $= 12$, which is the number of degrees between one tooth and the next. Between 8 teeth there are seven such spaces and $12 \times 7 = 84$, and $84 + 6$ (half of one space) $= 90$ the number of degrees between the centres of the pallets. The proper position for the pallet staff centre will be indicated by the intersection of tangents to the wheel circle drawn from the centres of the pallets. But it happens that a tangent of $45° =$ the radius and therefore the practical method adopted is to make the pallet arms from the staff hole to the centre of impulse face, equal to the radius of the escape wheel. If we take the radius of wheel to be = 1, it will be found that with the pallet arms this length the height of the pallet staff hole from the centre of the wheel will be 1·41 and the horizontal distance between the impulse faces of the pallets will be 1·41 also.

Dead Beat or "Graham" Escapement.

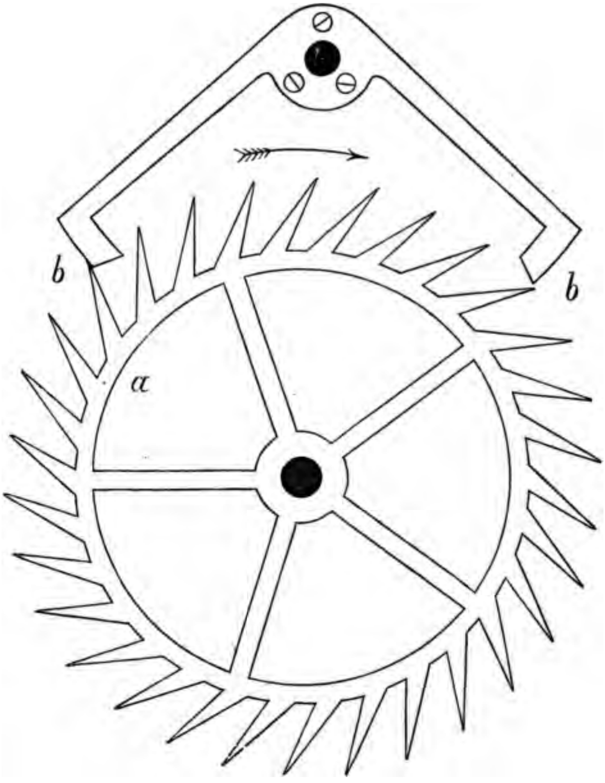


Fig. 37.

a. Escape Wheel. | *b. Pallets.*

The width of each pallet is equal to half the distance between one tooth and the next less drop, which need not be much if the escape wheel teeth are made thin as they should be. The dead faces of the pallets are curves struck from the pallet staff hole.

The escaping arc = two degrees is divided into 1½° of impulse and ½° of rest. 1½° of impulse is quite enough if the escapement is properly made and if increased beyond 2° it will be at the cost of the timekeeping properties of the clock on account of the thickening of the oil already referred to.

From the centre of the wheel set off two radial lines barely 3° on each side of the radial lines already drawn to mark the centre of the pallets. Then strike the curved dead faces of the pallets just touching the radial lines last drawn.

Now from the pallet centre draw lines through the spot where the curved locking face of each pallet cuts the wheel circle. If you look at the engraving you will see that a wheel tooth is resting on the left hand pallet. The amount of this rest is ½° as already stated. Mark off this ½°, which gives the position of the locking corner of the pallet, and then set off another line 1½° below it, which will mark the spot for the other corner of the pallet. On the right hand pallet the line already drawn marks the extreme corner and it is only necessary in order to get the locking corner to set off a line 1½° ABOVE it.

The wheel teeth diverge from a radial line about 10°, so that their tips only touch the dead faces of the pallets.

The wheel is of hard hammered brass and for regulators is made from an inch and a half to two inches in diameter and very light. The pallets are usually of steel nicely fitted to the arbor and in addition screwed to a collet thereon as shown. In the best clocks the acting faces are jewelled. Sometimes the pallet arms are cast of brass and the pallets formed of solid jewels.

The Graham Escapement requires a heavy pendulum, especially if the train is comparatively rough. The clock weight must be sufficient to overcome incŕeased resistanee arising from inaccuracy of work. Consequently when the train runs freely so much extra pressure is thrown upon the dead faces of the pallets that a light pendulum has not enough energy to unlock and the clock stops.

For clocks with shorter than half seconds pendulums the pallets are generally made "half dead," that is the rests instead of being curves struck from the pallet staff hole are formed so as to give a slight recoil to the wheel.

The Pin Wheel Escapement.

(Invented by Lepaute about 1753.)

This escapement (shown in Fig. 38) is used principally in turret clocks, for which it is, in some respects, more suitable than the Graham. The pressure of the pins on both pallets is downwards, and therefore the shake in the pallet staff hole does not affect the action of the escapement. The chief objection to it practically is the difficulty of keeping the pins lubricated, the oil being drawn away to the face of the wheel. To prevent this a nick is sometimes cut round the pins, close to the wheel, but this weakens the pins very much.

Lepaute made the pins semi-circular, and placed alternately on each side of the wheel so as to get the pallets of the same length. This requires double the number of pins, and there is no real disadvantage in having one pallet a little longer than the other, provided the short one is put outside, as shown in the drawing. Sir Edmund Beckett introduced the practice of cutting a piece off the bottoms of the pins, which is a distinct improvement, for if the pallet has to travel past the centre of the pin with a given arc of vibration before the pin can rest, the pallets must be very long unless very small pins are used.

The escaping arc is generally 2°, and the diameter of the pins is then 4° measured from the pallet staff hole.

Then with a given diameter of pin, to find the mean length of pallets divide the given diameter by ·069.

Or if the mean length of pallets is given, the diameter of pins may be found by multiplying the given length by .069.

The opening between the extreme points of the pallets = 2°, that is, half the diameter of the pins.

With an escaping arc of 3° the mean length of the pallet arms is ten times the diameter of the pins.

The angle of impulse is divided between the pins and the pallets, and care must be taken that the pallets are not cut back too much. When a pin escapes from one pallet the bottom of the succeeding pin must fall safely on the rest of the other pallet. It is best before finishing the impulse planes to place the pallets in position and mark them off with reference to the pins. The thickness of the two pallets and one pin contained between them equals, less drop which is very small, the space between two pins from centre to centre.

The pallets are of steel, hardened at the acting parts, and screwed to a collar on the pallet staff. The rests are slightly rounded so as to present less surface to the pins and the curves

Pin Wheel Escapement.

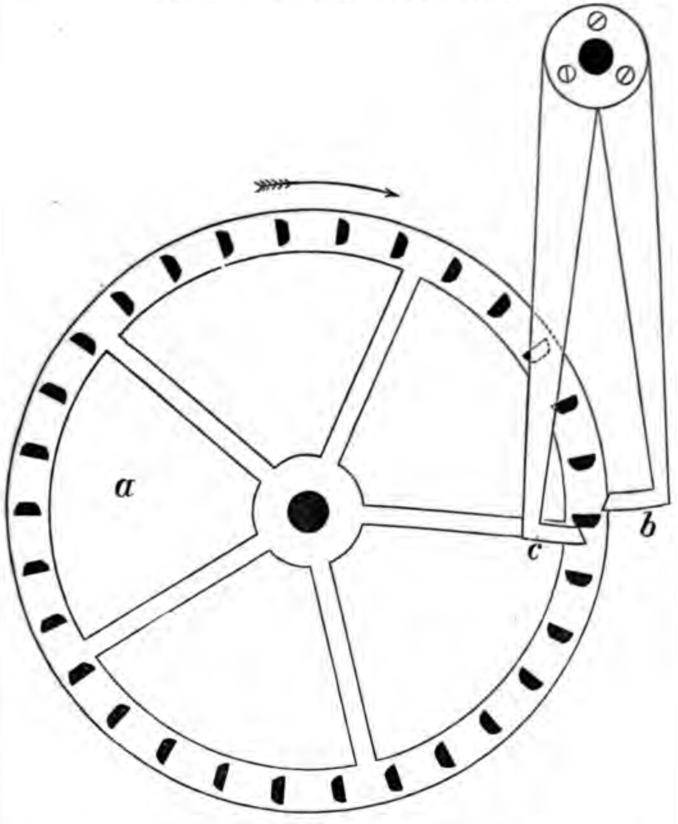


Fig. 38.

a. Escape Wheel. | *b. and c. Pallets.*

struck from a little below the pallet staff hole so as to be hardly "dead." The pins should be of gun metal or very hard brass, or aluminium bronze, round when screwed into the wheel and cut to shape in an engine afterwards.

Double Three Legged Gravity Escapement.

Invented by E. B. Denison (Sir E. Beckett, Q.C.), 1854.

For large turret and other clocks which have to move a number of heavy hands exposed to wind and snow the Graham and similar escapements are not perfectly adapted. The driving weight of the clock must be sufficient to move the hands under the most adverse

Double Three Legged Gravity Escapement.

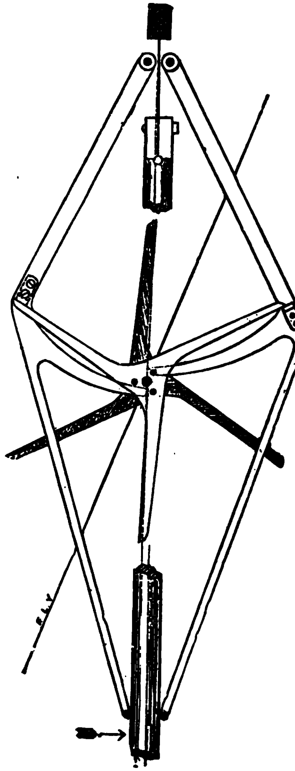


Fig. 39.

circumstances. Then at times when the wind and snow assist the hands in their motion the whole of the superfluous power is thrown on the escapement, and accurate performance cannot be expected. The custom has been to use for such clocks a remontoire of some kind, which is an arrangement by which the train instead of impelling the pendulum direct winds up a spring. This spring in unwinding administers a constant impulse to the pendulum. A gravity escapement partakes somewhat of this principle. The train raises an arm of certain weight a constant distance and the weight of this arm in returning impels the pendulum. Until Mr. Denison invented the double three legged for the great clock at the Houses of Parliament gravity escapements were rather regarded with suspicion as having a tendency to trip.

Denison's double three-legged gravity escapement shown in Fig. 39 consists of two gravity impulse pallets pivotted as nearly as possible in a line with the bending point of the pendulum spring. The locking wheel is made up of two thin plates having three long teeth or "legs" each. These two plates are squared on the arbor a little distance apart, one on each side of the pallets, They are connected by means of a three-leaved pinion. In the drawing one of the front legs is resting on a block screwed to the front of the right hand pallet. This forms the locking. There is a similar block screwed to the back of the left hand pallet for the legs of the back plate, which is shaded in the drawing, to lock upon. Projecting from each of the pallets is an arm. The tip of the one on the right hand pallet is just in contact with one of the leaves of the three leaved pinion.

The pendulum is travelling in the direction indicated by the arrow and the left hand pallet is delivering impulse across the line of centres. The pendulum rod in its swing will push the right hand pallet far enough for the leg of the front locking plate, which is now resting on the block, to escape. Directly it escapes the left hand pallet is lifted free of the pendulum rod by the lowest leaf of the pinion. After the locking wheel has passed through 60 degrees a "leg" of the back locking plate is caught by the locking block on the left hand pallet.

As the three-leaved pinion always lifts the pallets the same distance the pallets in returning give a constant impulse to the pendulum. The friction in unlocking would, of course, vary with the pressure transmitted through the train, but the effect of such variation is found to be practically of no moment. To avoid any jar when the locking leg falls on the block there is a fly kept, by a spring, friction tight on an enlarged portion of the arbor. This fly causes the legs to fall smoothly and dead on the blocks and thus avoids all danger of tripping.

All the parts are made very light of steel with the acting surfaces hardened. The radius of the three-leaved pinion should not be more than $\frac{1}{24}$th of the radius of the locking legs. The leaves should be placed as shown, one in a line with each of the legs of the locking plates, so that the lifting is performed across the line of centres. The distance of the centre of the escape wheel from the pivots of the pallets = the diameter of the escape wheel. The length of the tails of the pallets is immaterial. For symmetry they are generally made as shown. The most frequent mistake in constructing this escapement is that the parts, especially the locking plates, which can hardly be too light, are made too heavy. Sir E. Beckett suggests that the fly should be made of aluminium for lightness.

This escapement, so excellent for turret clocks, is occasionally used for regulators and other clocks with seconds pendulum. It may, perhaps, when thoroughly well made be better than the Graham for such a purpose, when the locking blocks are jewelled, as it is free from the error due to thickening of the oil, but from the small number of teeth in the escape wheel it requires in the train either very high numbered wheels or an extra wheel and pinion. This is a distinct advantage in a turret clock, because the large amount of power required to drive the leading off rod is thereby more reduced by the time it reaches the escapement. In a regulator the extra pair of wheels is a drawback sufficient to prevent its adoption considering the extra cost of the escapement and the good performance of the Graham.

The Anchor or "Recoil" Escapement.

(Invented by Dr. Hooke about 1675.)

The Recoil Escapement is the one most generally used for the ordinary run of Dials and House Clocks. When well made it gives very fair results, but the pallets are often very improperly formed although none of the escapements are easier to set out correctly.

There are still people who believe the Recoil to be a better escapement than the Dead Beat—mainly because the former requires a greater variation of the driving power to affect the extent of the vibration of the pendulum than the latter does. But the matter is beyond argument; the recoil can be cheaply made, and is a useful escapement, but beyond question is inferior to the dead beat for timekeeping.

Recoil Escapement.

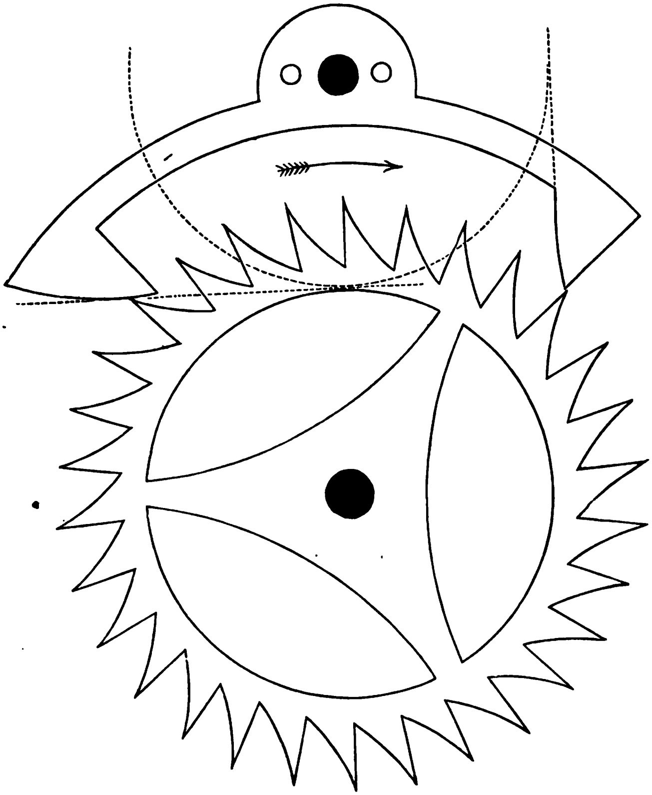


Fig. 40.

There is no rest or locking for the pallets, but directly the pendulum in its vibration allows a tooth, after giving impulse, to escape from the impulse face of one pallet, the course of the wheel is checked by the impulse face of the other pallet receiving a tooth. The effect of this may be seen on looking at the drawing (Fig. 40), where the pendulum, travelling to the right, has allowed a tooth to fall on the left hand pallet. The pendulum, however, still continues its swing to the right, and in consequence the pallet pushes the wheel back, thus causing the recoil which gives the name to the escapement. It is only after the pendulum comes to rest and begins its excursion the other way that it gets any assistance from the wheel, and the difference between the forward motion of the wheel and its recoil forms the impulse.

To Set Out the Escapement.—Draw a circle representing the escape wheel, which we assume to have thirty teeth, of which the anchor embraces eight. Mark off the position of four teeth on each side of the centre and draw radial lines which will represent the backs of the teeth.

NOTE.—Space between one tooth and the next $= \frac{360}{30} = 12$; and 8 teeth $= 7$ spaces $= 84°$. Then $\frac{84}{2} = 42°$ to be set off on each side of the centre.

The distance of the pallet staff centre from the centre of escape wheel = radius of wheel × 1·4. From the pallet staff centre describe a circle whose radius = seven-tenths of the radius of escape wheel, that is half the distance between the escape wheel and pallet staff centres. Tangents to this circle just touching the tips of the teeth already marked, as shown by dotted lines in the drawing, would then form the faces of the pallets if they were left flat. Each of the pallets is made of such a length that it intersects the path of the wheel teeth by half the amount of impulse measured from the pallet staff centre. The impulse is usually from 3° to 4°. When a tooth drops off one pallet, which is the position of the escapement in the drawing, the amount of impulse is shown by the intersection of the other pallet in the wheel.

The pallet faces are generally curved, full in the middle, as shown in Fig. 40. The object of curving the pallets is to lessen the "pitting," which the wheel teeth make on the pallets. There will, however, be very little "pitting" if the wheels are made small and light and there is not excessive drop to the escapement.

The advantage of making the backs of the escape wheel teeth radial and the foresides curved, as shown in Fig. 40, is that if the pendulum gets excessive vibration the pallets butt against the roots of the teeth and the points are uninjured. The pallets in the figure are a trifle too wide.

There is another form of the Recoil Escapement often used in long cased clocks, in which the anchor embraces ten teeth of the escape wheel, and the foresides of the teeth are radial. It is shown in Fig. 41. In other respects the construction is substantially the same as the one just described.

Recoil Escapement for Long Case Clocks.

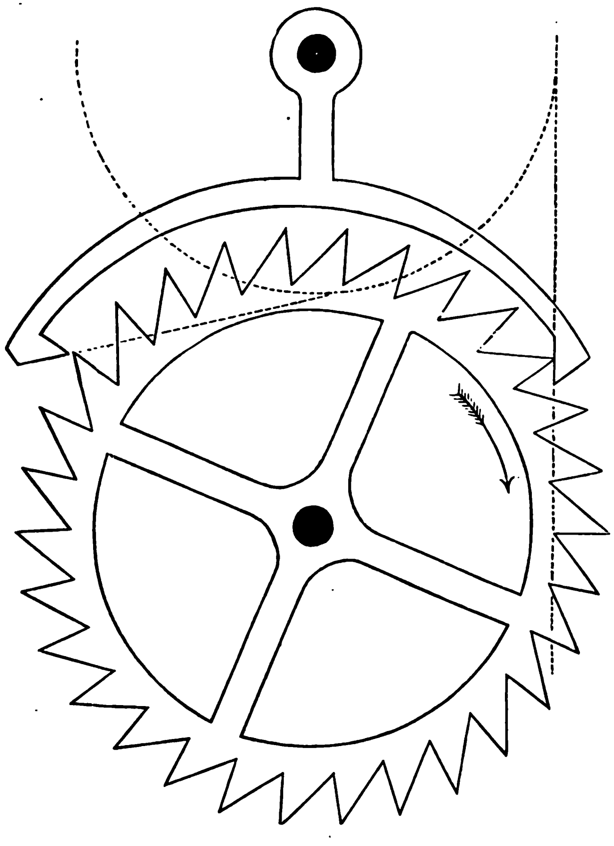


Fig. 41.

Brocot's Pin Pallet Escapement.

This excellent escapement, rarely seen except in small French clocks, appears to be worthy of more extended use. The fronts of the teeth of the escape wheel are sometimes made radial, as shown in Fig. 42 ; sometimes cut back so as to bear on the point only,

Brocot's Pin Pallet Escapement.

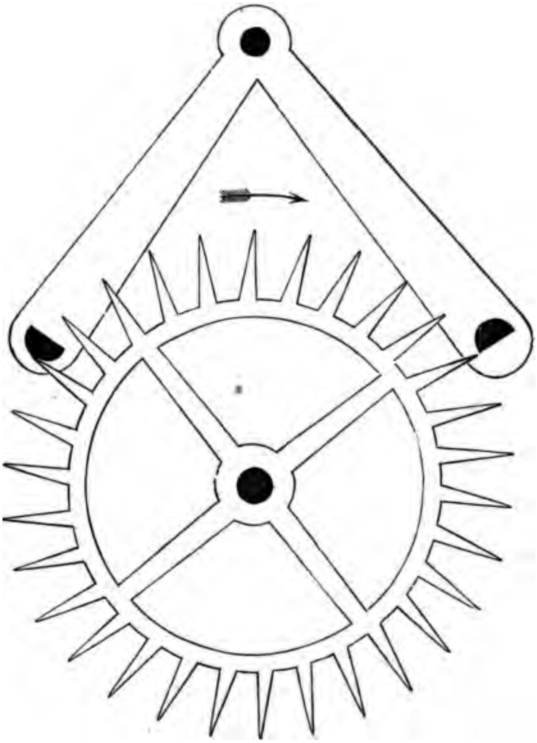


Fig. 42.

like the "Graham"; and sometimes set forward so as to give recoil to the wheel during the motion of the pendulum beyond the escaping arc. The pallets, generally of ruby, are of semi-circular form.

The diameter of each is a trifle less than the distance between two teeth of the large wheel. The angle of impulse in this escapement bears direct reference to the number of teeth embraced by the pallets. Ten is the usual number, as shown in the drawing. The distance between the escape wheel and pallet staff centres should not be less than the radius of the wheel × 1·7. This gives about 4° of impulse measured from the pallet staff centre.

English clockmakers rather object to this escapement on account of the difficulty of keeping oil to the pallets. The effect of the want of oil is much more marked if the pallets are made of steel instead of jewel. Any tendency of this escapement to set is generally met by flattening the curved impulse faces of the pallets as indicated by the dotted line across the right hand pallet.

Single Beat "Drum" Escapement.

The escapement used in French Drum Clocks is a continual source of trouble to English clock jobbers. It receives impulse at every other vibration only. The clocks have going barrels and the idea of the escapement appears to be that by providing a long frictional rest on one of the pallets the extra pressure of the escape wheel tooth when the main spring is fully wound will be sufficient to prevent any considerable increase in the arc of vibration of the pendulum. But the clocks often stop from deficiency of power when the spring is nearly down, and stop when they are fully wound because the small and light pendulum has not energy enough to unlock the pallet. The best that can be done is to alter the resting pallet to the form indicated by the dotted lines in figure 43, and see that wheel teeth and pallets are well polished.

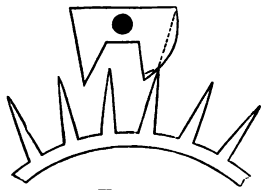


Fig. 43.

Simple Calendar Work.

A simple calendar work is shown in Fig. 44. Gearing with the hour wheel is a wheel having twice its number of teeth, and turning therefore once in 24 hours. A three armed lever is planted just above this wheel; the lower arm is slotted and the wheel carries a

Simple Calendar Work.

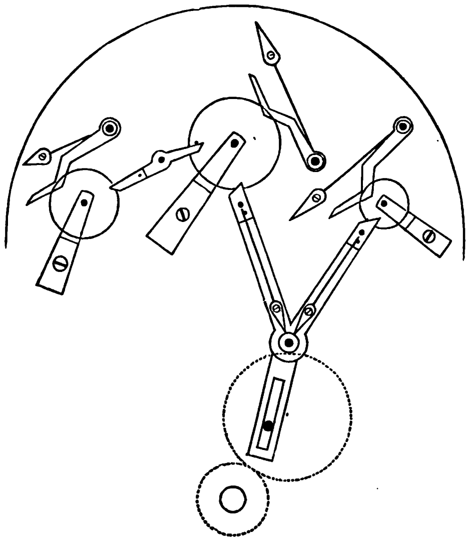


Fig. 44.

pin which works in this slot so that the lever vibrates to and fro once every 24 hours. The three upper circles in the drawing represent three star wheels. The one to the right has seven teeth corresponding to the days of the week; the centre one has 31 teeth for the days of the month; and the left hand one has 12 teeth for the months of the year. Every time the upper arms of the lever vibrate to the left they move forward the day of the week and day of the month wheels each one tooth. The extremities of the levers are jointed so as to yield on the return vibration and are brought into position again by a weak spring as shown. There is a pin in the day of the month wheel which, by pressing on a lever once every revolution, actuates the month of the year wheel. This last lever is also jointed and is pressed on by a spring so as to return to its original position. Each of the star wheels has a click or jumper kept in contact by means of a spring.

For months with less than 31 days the day of the month hand has to be shifted forward.

Perpetual Calendar Work.

Figs. 45, 46, 47 and 48 illustrate M. Brocot's arrangement of calendar, lunation, and equation work. The various parts are planted on a circular plate, of which the inner side, containing the pieces for indicating the days of the week and the days of the month, is shown in fig. 46. Fig. 48 shows the outer side of the plate, which is devoted to the mechanism for producing the phases of the moon and the equation of time. To this side of the plate the dial Fig. 47 is attached.

The calendar is actuated by means of a pin *e* fixed to a wheel of the movement which turns once in 24 hours. Two clicks G and H are pivotted to the lever M *m*, G is kept in contact with a ratchet wheel of 31 teeth, and H with a ratchet wheel of seven teeth. As a part of these clicks and wheels is concealed in Fig. 46 they are shown separately in Fig. 45.

When the lever M *m*, is moved by the pin *e*, the clicks G and H slip under the teeth, their beaks pass on to the following tooth, and the lever then not leaning on the pin *e*, falls quickly by its own weight, and makes each click leap a tooth of the respective wheels of seven and 31 teeth. The arbors of these wheels pass through the dial (*Fig. 47*), and have each an index which, at every leap of its own wheel, indicates on its special dial the day of the week and the day of the month. A roll or jumper, kept in position by a sufficient spring, keeps each wheel in its place during the interval of time which separates two consecutive leaps.

This motion clearly provides for the indication of the day of the week, and would be also sufficient for the days of the month if the index were shifted by hand at the end of the short months.

To secure the proper registration of the months of 30 days, for February of 28 during three years, and of 29 in leap year, M. Brocot makes the following provision. The arbor A of the month wheel goes through the circular plate and on the other side is fixed

Brocot's Perpetual Calendar.

Fig. 45.

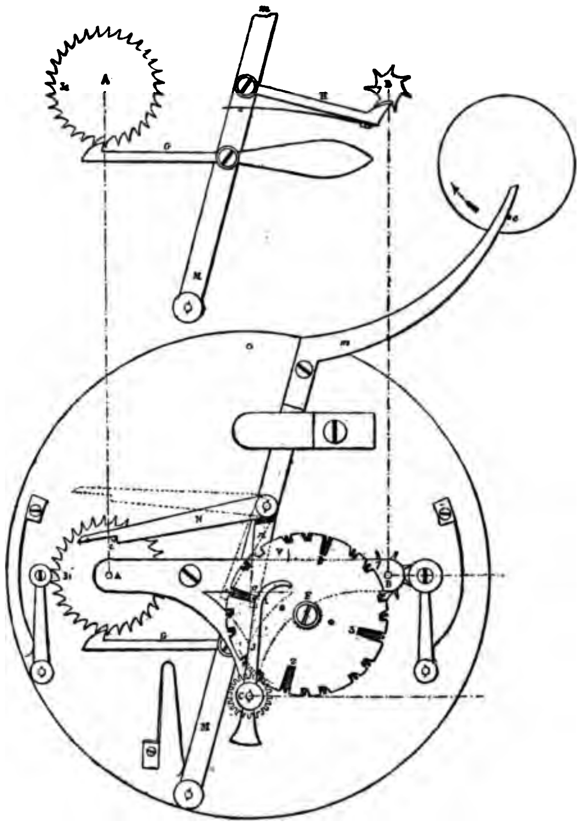


Fig. 46.

(see Fig. 48) a pinion of 10. This pinion, by means of an intermediate wheel D, works another wheel (centered at *c*) of 120 teeth, and consequently turning once in a year. The arbor of this last wheel bears an index indicating the name of the month. The arbor C

Brocot's Perpetual Calendar.

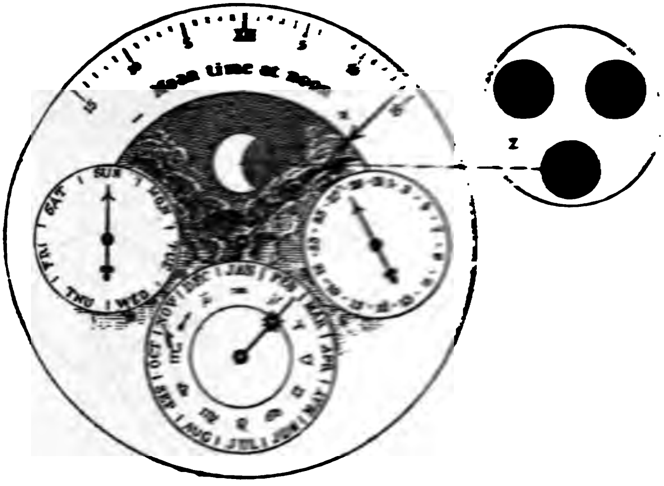


Fig. 47.

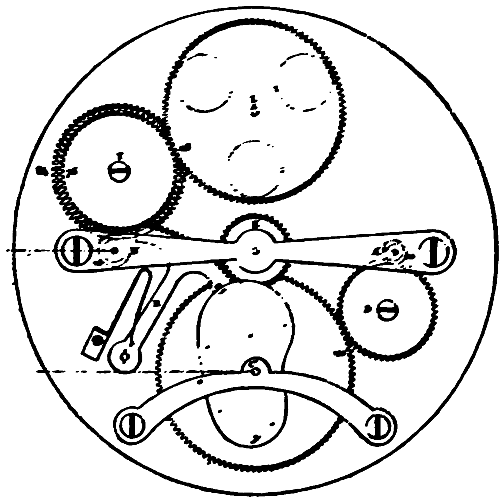


Fig. 48.

goes through the plate and at the other end (see Fig. 46) is fixed a little wheel gearing with a wheel having four times as many teeth, and which is centered at F. This wheel is partly concealed in Fig. 46 by a disc V, which is fixed to it, and with the wheel makes a turn in four years. On this disc are made 20 notches of which the 16 shallowest correspond to the months of 30 days, a deeper notch corresponds to the month of February of leap year, and the last three deepest to the month of February of common years in each quaternary period. The uncut portions of the disc correspond to the months of 31 days in the same period.

The wheel of 31 has a pin *i*, placed before the tooth which corresponds to the 28th of the month. On the lever M *m*, is pivotted freely a bell-crank lever, N *n*, having at the extremity of the arm *n*, a pin *o*, which leans its own weight upon the contour of the disc V, or upon the bottom of one of the notches, according to the position of the month, and the arm N is therefore higher or lower according to the position of the pin *o* upon the disc.

It will be easy to see that when the pin *o* rests on the contour of the disc, the arm N of the bell-crank lever is as high as possible as it is dotted in the figure, and then the 31 teeth of the month wheel will each leap successively one division by the action of the click G, till the 31st day. But when the pin *o* is in one of the shallow notches corresponding to the months of 30 days, the arm N of the bell-crank lever will take a lower position, and the inclination that it will have by the forward movement of the lever M *m* will bring on the 30th the pin *i* in contact with the bottom of the notch, just as the lever has accomplished two-thirds of its movement, so the last third will be employed to make the wheel of 31 advance one tooth, and the hand of the dial by consequence marks 31st, the quick return of the lever putting this hand to the 1st. If we suppose the pin *o* in the shallowest of the four deep notches, that one for February of leap-year, the end of the arm N will take a position lower still, and on the 29th the pin *i* will be met by the bottom of the notch, just as the lever has made one-third of its course, so the other two-thirds will serve to make two teeth of the wheel of 31 jump. Then the hand of the dial will indicate 31, the ordinary quick return of the detent putting it to the 1st.

Lastly, if as it is represented in the figure, the pin *o* is in one of the three deepest notches, corresponding to the months of February in ordinary years, the pin will be in the bottom of the notch on the 28th just at the moment the lever begins its movement, and three teeth will pass before the return of the lever makes the hand leap from the 31st to the 1st.

The pin *o* easily gets out of the shallow notches, which, as will be seen, are sloped away to facilitate their doing so. To help it out of the deeper notches there is a weighted finger *j* on the arbor of the annual wheel. This finger having an angular movement much larger than the one of the disc G, puts the pin *o* out of the notch before the notch has sensibly changed its position.

Phases of the Moon.—The phases of the moon are obtained by a pinion of 10 on the arbor B, which gears with a wheel of 84 teeth, fixed on another of 75, which last gears with a wheel of 113, making one revolution in three lunations. By this means there is an error only of ·00008 day per lunation. On the wheel of 113 is fixed a plate Z, on which are three discs coloured blue, having between them a distance equal to their diameter, as shown in Fig. 47; these discs slipping under a circular aperture made in the dial, produce the successive appearance of the phases of the moon.

Equation of Time.—On the arbor of the annual wheel is fixed a brass cam or "kidney piece" *y*, on the contour of which leans the pin *s*, fixed to a circular rack R. This rack gears with the central wheel K, which carries the hand for the equation. That hand faces XII the 15th April, 14th June, 1st September, 25th December. At those dates the pin *s* is in the position of the four dots marked on the kidney piece. The shape of the kidney piece must be such as will lead the hand to indicate the difference between solar and clock time as given in the table at page 9.

Manner of adjusting the Calendar.—Firstly, the return of the lever M *m* must be made at the moment of midnight. To adjust the hand of the days of the week look at an almanac and see what day before the actual date there was a full or new moon. If it was new moon on Thursday it would be necessary, by means of a small button fixed at the back, on the axis of the hand of the week, to make as many returns as requisite to obtain a new moon, this hand pointing to a Thursday, and after to bring back the hand to the actual date, passing the number of divisions corresponding to the days elapsed since the new moon.

To adjust the hand of the month, see if the pin *o* is in the proper notch, if for the leap-year it is in the month of February in the shallowest of the four deep notches *o*; if for the same month of the first year after leap-year then the pin should be of course in the notch 1, and so on.

Hour and Half-Hour Striking Work.

Fig. 49 is a view of the front plate of an English striking clock on the rack principle, the invention of Tompion, which is the most reliable and the most generally used now even for turret clocks. The going train occupies the right and centre and the striking train the left hand on the other side of the plate. The position of the barrels is indicated by their ratchets, and the position of the fusees by the winding squares which are on the same level as the centre arbor. The connection between the going train and the striking work is by means of the *motion wheel on the centre arbor, and connection is made between the striking train and the striking work by the gathering pallet which is fixed to the arbor of the last wheel but one of the striking train and also by the warning piece which is shown in white on the boss of the lifting piece. This warning piece goes through a slotted hole in the plate and during the interval between warning and striking stands in the path of a pin in the last wheel of the striking train, called the warning wheel.

The motion wheel on the centre arbor, turning once in an hour, gears with the minute wheel, which has an equal number of teeth. These two wheels are indicated by dotted circles. There are two pins equidistant from the centre of the minute wheel which in passing raise the lifting piece every half-hour. Except for a few minutes before the clock strikes, the striking train is kept from running by the tail of the gathering pallet resting on a pin in the rack. Just before the hour, as the boss of the lifting piece lifts the rack hook, the rack impelled by a spring at its tail falls back until the pin in the lower arm of the rack is stopped by the snail. This occurs before the lifting piece is released by the pin in the minute wheel and in this position the warning piece stops the train. Exactly at the hour the pin in the minute wheel gets past the lifting piece which then falls and the train is free. For every hour struck the gathering pallet, whieh is really a one-tooth pinion, gathers up one tooth of the rack. After it has gathered up the last tooth its tail is caught by the pin in the rack and the striking ceases.

The snail is mounted on a star wheel placed so that a pin in the motion wheel on the centre arbor moves it one tooth for each revolution of the motion wheel. The pin in moving the star wheel presses back the click or "jumper," which not only keeps the star wheel steady but also completes its forward motion after the pin has

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*** Clockmakers call this which corresponds to the canon pinion in watches the minute wheel. I use the term motion wheel to distinguish it from the wheel gearing with it to which the name "minute wheel" is also applied.**

pushed the tooth past the projecting centre of the click. The steps of the snail are arranged so that at one o'clock it permits only sufficient motion of the rack for one tooth to be gathered up and at every succeeding hour additional motion equal to one extra tooth.

The lower arm of the rack and the lower arm of the lifting piece are made of brass and thin, so as to yield when the hands of the

Hour and Half-Hour Striking Mechanism.

(Half Full Size)

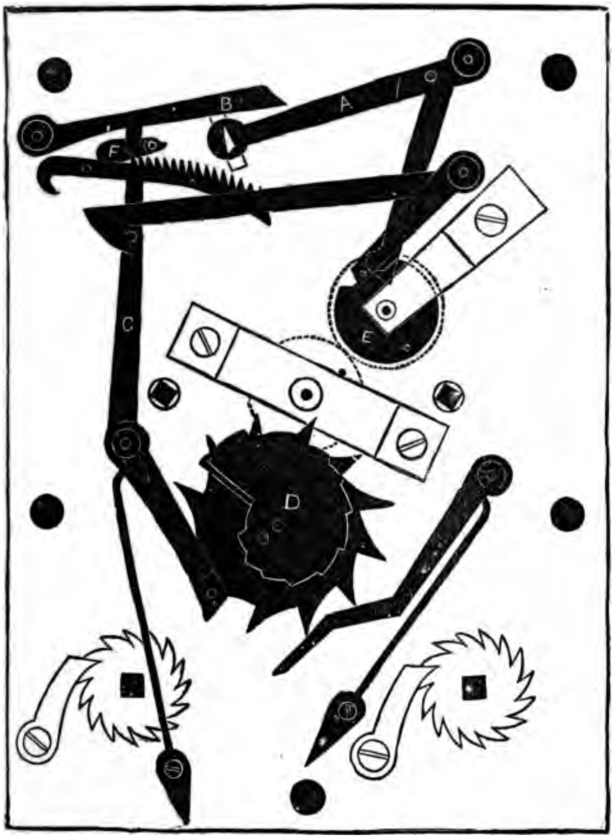

Fig. 49.

A. *Lifting Piece.* | D. *Hour Snail.*
B. *Rack Hook.* | E. *Half-Hour Cam.*
C. *Rack.* | F. *Tail of Gathering Pallet.*

For the arrangement of the Wheels in a Striking Train see Fig. 51.

clock are turned back ; the lower extremity of the lifting piece is a little wider and bent to a slight angle with the plane of the arm, so as not to butt as it comes into contact with the pin when this is being done.

The snail is sometimes placed upon the centre arbor instead of on a stud with a star wheel as shown, but the position of the snail is then not so definite owing to the backlash of the motion wheels and besides a smaller snail must be used unless it is brought out to clear the nose of the minute wheel cock.

Half-Hour Striking.—The usual way of getting the clock to strike one at the half-hour is by making the first tooth of the rack lower than the rest and placing the second pin in the minute wheel a little nearer the centre than the hour pin, so that the rack hook is lifted free of the first tooth only at the half-hour. But this adjustment is too delicate and the action is liable to fail altogether or to strike the full hour from the pin getting bent or from uneven wear of the parts. The arrangement shown in Fig. 49 was devised by Mr. Barnsdale, and appears to be much safer, although it costs a little more. One arm of a bell crank lever rests on a cam fixed to the minute wheel. The cam is shaped so that just before the half-hour the other extremity of the bell crank lever catches a pin placed in the rack and permits it to move the distance of but one tooth. This is the position shown in the drawing. After the half-hour has struck the cam carries the catch free of the pin.

Division of the Hour Snail.—The distance of the pin in the lower arm of the rack should be equal to the distance between the centre of the stud hole and the centre of the snail. The difference between the radius of the top and the radius of the bottom step of the snail may be obtained by multiplying the distance of twelve teeth of the rack by the length of the lower arm and dividing the product by the length of the upper arm. Divide the circumference of a circular piece of stout well hammered brass plate into 12 parts and draw radial lines as shown in Fig. 50. Each of these spaces is devoted to a step of the snail. Draw circles representing the top and bottom step. Divide the distance between these two circles into eleven equal parts and at each division draw a circle which will represent a step of the snail. The rise from one step to another should be sloped as shown, so as to throw off the pin in the rack arm if the striking train has been allowed to run down, and it should be resting on the snail when it is desired to turn the hands back. The rise from the bottom to the top step is bevelled

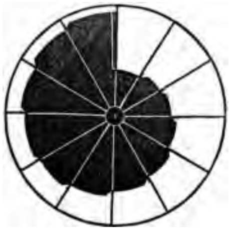

Fig. 50.

off, as shown by the double line, so as to push the pin in the rack arm on one side and allow it to ride over the snail if it is in the way when the clock is going.

Clockmakers generally mark off the snail on the clock itself after the rest of the striking work is planted. A steel pointer is fixed in the hole of the lower rack arm and the star wheel jumped forward twelve teeth by means of the pin in the motion wheel. After each jump a line is marked on the blank snail with the pointer in the rack arm by moving the rack arm. These twelve lines correspond to the twelve radial lines in Fig. 50. The motion wheel is then turned sufficiently to carry the pin in it free of the star wheel and the star wheel click fastened back so as to leave the star wheel and blank snail quite free on their stud. The rack hook is placed in the first tooth of the rack and while the pointer in rack arm is pressed on the blank snail the latter is rotated a little so that a curve is traced on it. The rack hook is then placed in the second and afterwards in the succeeding teeth consecutively and the operation repeated till the twelve curves are marked. There is one advantage in marking off the snail in this way. Should there be any inaccuracy in the division of the teeth of the rack the steps of the snail are thus varied to suit it.

Clocks striking one at the hour have the hammer tail lifted by a snail on the minute wheel. Although a snail of this kind is not divided into steps it may be set out on the plan of Fig. 50, the contour of the snail being represented by a curve cutting through the intersection of the circles with the radial lines. If formed in this manner it is evident the hammer tail will be lifted uniformly throughout the revolution of the minute wheel. Sometimes these snails are wrongly made so as to do nearly the whole of the lifting as the hour approaches, and the extra strain on the minute wheel stops the clock, or causes the motion wheel to slip on the centre arbor.

Three Train Quarter Chime Clock.

Fig. 51 is a front elevation of the mechanism of a quarter clock, as arranged by Mr. Barnsdale. The going train occupies the centre of the plate; the striking train is planted on the left, and the chiming train on the right hand. All the train wheels are represented by circles except the fusee wheel of the going train.

Going Train.

Fusee Wheel 96	Centre Wheel 84	Third Wheel 78
Pinion ... 8	Pinion ... 7	Pinion ... 7

Striking Train.

Fusee Wheel 84	Pin Wheel 64	Pallet Wheel 70	Warning Wheel 60
Pinion ... 8	Pinion ... 8	Pinion ... 7	Fly Pinion ... 7
	8 Pins in Pin Wheel		

As the gathering pallet makes one complete revolution for every blow struck, the pin wheel must contain as many times more teeth than the pinion or the gathering pallet arbor as there are pins in the pin wheel. The number of teeth in the pallet wheel must also be a multiple of the teeth in the pinion on the warning wheel arbor.

Chiming Train.

Fusee Wheel 100	Second Wheel 80	Pallet Wheel 64	Warning Wheel 50
Pinion ... 8	Pinion ... 8	Pinion ... 8	Fly Pinion ... 8
		Chime Wheel 40	

The barrels for the going and striking parts are each $2\frac{3}{8}$ inches in diameter and the barrel for the chiming part $2\frac{3}{4}$ inches.

There are four pins in the minute wheel for raising the quarter lifting piece and therefore the quarter rack hook every quarter of an hour. One, two, three or four quarters are chimed according to the position of the quarter snail which turns with the minute wheel. At the hour when the quarter rack is allowed to fall its greatest distance it falls against the bent arm of the hour rack hook and releases the hour rack. As the last tooth of the quarter rack is gathered up, the pin in the rack pulls over the hour warning lever and lets off the striking train. The position of the pieces in the drawing is as they would be directly after the hour was struck.

This is clearly a much better arrangement than the usual flirt, which absorbs more power and is less certain in its action.

Striking Mechanism of Quarter Chime Clock.

(Half Full Size.)

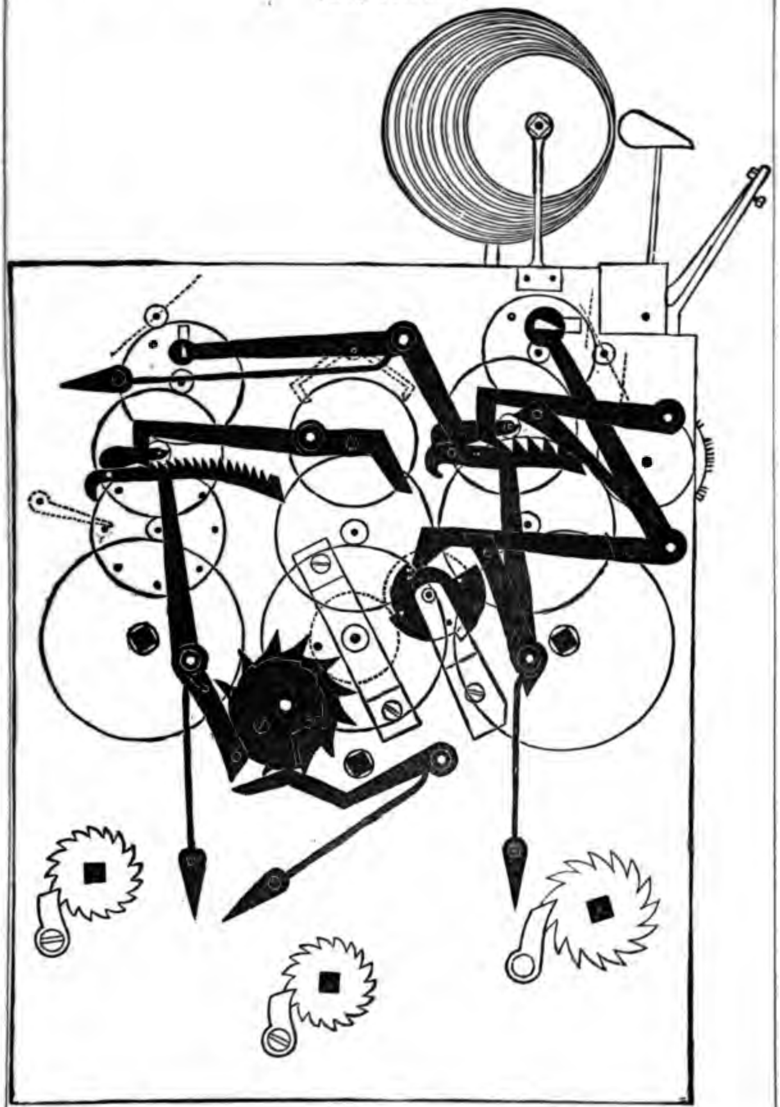

Fig. 51.

Turret Clock Striking.—For lifting the hammer tails of small clocks, pins in the wheel as shown in Fig. 51, do very well, but in turret clocks where the hammers are heavy and it is a consideration to economize the power steel cams formed so that at the beginning and end of the lift the end of the lever bears on the cam should be used. The power should also be taken from the lever on the same side of its centre of motion as the cams act, as shown in Fig 52; in fact the hammer rods should be as near the cams as is practicable. In the figure the hammer rod is attached to the end of the longer lever and the shorter lever, pressed downwards by the wheel, is just leaving the face of the cam. I fancy Sir Edmund Beckett was the first to use cams of this form for lifting the hammer. They are so used in the Westminster clock and the arrangement is described by him in detail in his book on clocks.

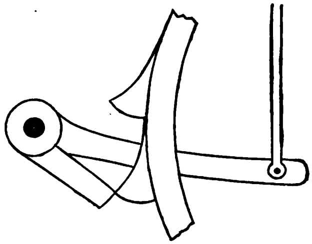

Fig. 52.

"Maintaining Power."

Harrison's Maintaining Spring.—To obviate the danger of a watch or clock stopping while being wound Harrison introduced the contrivance now used in all fusee watches, as well as in regulators and the better class of house clocks.

Fig. 53 is a view of the larger end of a watch fusee, which is fixed tight to the winding arbor. The great wheel rides loose on the arbor as does also a thin steel ratchet wheel as large as the fusee, which is placed between the fusee and great wheel. There is a smaller ratchet wheel whose teeth are cut the reverse way, let into

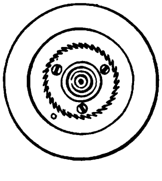

Fig. 53.

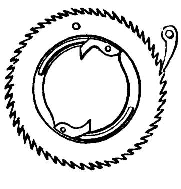

Fig. 54.

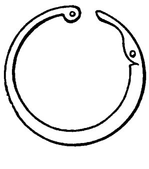

Fig. 55.

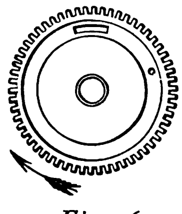

Fig. 56.

and screwed to the fusee, as seen in Fig. 53. Fig. 54 shows that side of the larger ratchet wheel which is placed next to the fusee.

The two clicks thereon take into the ratchet on the fusee and thus establish connection between the two pieces. On the inner side of the larger ratchet wheel is fixed one end of the spring Fig. 55. Fig. 56 shows the great wheel, round the inner face of which a recess is turned to cover the spring so that the great wheel can be brought close to the large steel ratchet wheel. Projecting from the free end of the spring is a round pin of a size to pass freely into the slot shown in the great wheel. This pin makes the connection between the larger ratchet and the great wheel. The spring being made rather weaker than the force of the mainspring of the watch exerted at the radius of the pin is bent up as the watch is going, when the great wheel rotates in the direction indicated by the arrow, and the teeth of the larger ratchet pass under the click. In winding, the fusee is turned the reverse way and the teeth of the smaller ratchet slip under the two clicks, which are pivoted on the larger ratchet. The spring connecting the larger ratchet to the great wheel then, in striving to unbend, drives the watch, the larger ratchet forming a resisting base; for it cannot go back with the fusee because the click which takes into it is pivoted to the watch plate.

In clocks the smaller ratchet is outside the barrel and has but one click, and instead of the spring let into the great wheel there is a stiff straight spring screwed to the larger ratchet, which presses on one of the arms of the great wheel.

Sun and Planet Maintainer.—In turret clocks there is often a weighted lever or segment brought to bear on the great wheel while winding, but this is open to the objection that it has to be renewed if the operation of winding takes long and also because after winding until the maintainer is removed there is considerable extra pressure on the escapement. In some of Arnold's watches is a continuous maintainer, which also appears to have been invented by Harrison. Although not so suited for watches as the maintainer already described, it appears to be admirably adapted for turret clocks, which take some time to wind. I have lately seen a turret clock by Messrs. Charles Frodsham and Co., with this maintainer, at St. Mark's Church, Victoria Park, which works most satisfactorily. The great wheel and barrel both ride loose on the arbor, to which is fixed a pinion represented by the smallest circle in Fig. 57. The largest circle represents a ring of internal teeth fixed to the side of the great wheel next to the barrel. There are two wheels which gear with both the pinion fixed to the barrel arbor and with the ring of internal teeth on the great wheel, as shown.

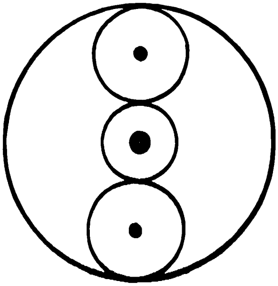

Fig. 57.

These two wheels run on studs in the end of the barrel. While the handle attached to the barrel arbor is turned as in winding a continuous pressure is exerted on the internal teeth, which really afford the resisting base in raising the weight. There is a ratchet wheel fixed to the barrel arbor with a click pivotted to the clock frame to prevent the weight running down when the winding is completed. During the going of the clock the barrel arbor remains stationary.

On Polishing.

The tools used for producing the beautiful polished and square surfaces to be found in watchwork may be divided into two general principles, first, where the work is rigid and receives a reproduction of a previously squared surface, and secondly, where the work is "swung" or arranged so as to yield to unequal pressure in polishing.

Polishers for steel are either of soft steel, iron, bell-metal, tin, zinc, lead or boxwood. They must in all cases be formed of softer material than the object to be polished; for instance, bell-metal, which brings up a good surface on hard steel, is unsuited for soft.

Polishers for brass are generally of tin or boxwood, with willow for finishing.

The polishing medium is either emery, which is used for grey surfaces, oilstone-dust, redstuff, or diamantine, used with oil.

Brass surfaces are generally "stoned" preparatory to polishing, that is, rubbed square with blue stone or water of Ayr stone and water or oil.

Mixing Polishing Material.—Red stuff should be thoroughly beaten up on glass or a polished steel stake to a stiff paste with very little oil. Far too much oil is often used and the mixture left thinner than it should be. Olive oil is not suitable, and if used the polishing stuff becomes sticky in a day or two. Refined sperm oil answers well. Diamantine should be mixed in the same way, as dry as possible, so that when it is used the polisher is only just damped with it.

Polishing Watch Wheels.—Escape wheels are generally fixed to a small brass block. The block is heated in a bluing pan and a piece of resin passed lightly over it so as to leave a very thin varnish only, which is quite enough to make the wheel adhere; there should be circles marked on the face of the block as a guide for fixing the wheel as nearly central as possible, or else a small pin in the centre of the block to go through the hole in the wheel with the same object. The wheel fixed to the block is first rubbed till quite flat on a piece of blue stone having a true face, which is kept moistened with water; it is rubbed with a circular motion by means of a pointer (generally a drill stock) pressed down on the middle of the back of the block, which is hollow as shown in the sketch (Fig. 58). The wheel is thoroughly cleaned and then polished on a block of grain tin with sharp red stuff and oil well beaten up previously. The block of tin rests on a leather pad. When one side of the wheel is finished it is placed again in the bluing pan. The old resin is cleaned off and the finished side of the wheel fixed to the block. After both sides are polished the wheel is placed in spirits of wine to remove any resin adhering to it. Solid train wheels are placed on a piece of cork screwed in the vice and rubbed with a piece of blue stone (previously rubbed on a stone to an even face) moistened with water. When the wheel is rubbed flat it is put in a pair of turns with a ferrule screwed on the arbor and revolved with a hair bow, and rubbed at the same time with a thin piece of blue stone, moistened with oil and having a perfectly flat face. This process must be continued till the wheel presents a perfectly smooth face, free from all marks and scratches. This point is important, as deep marks cannot be removed by the subsequent polishing, except by the sacrifice of much time and also of the squareness of the work. The wheel, having been well cleaned with bread (it should be seen that the bottoms of the *teeth are* quite clear) is next rubbed with a piece of flat boxwood and the unction or paste obtained by rubbing two blue stones together with clean oil, and afterwards, if brightness be desired, with a bit of cedar or willow, but a true, flat surface, the teeth also flat and not rounding at the sides or ends, is more to be sought after than mere polish. Pierced wheels are first rubbed flat on a cork either with a blue stone or water of Ayr stone. After cleaning they are polished with a soft tin polisher* and moder-

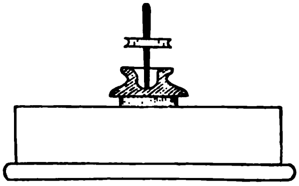

Fig. 58

Fig. 59.

* **Grain Tin Polishers.**—Owing to the extreme softness of this metal making a polisher at once light and rigid is a task of some difficulty. If it is to be of tin alone, the smallest size that will be of use in polishing wheels will be about seven-eighths of an inch broad, by five-sixteenths thick, and even this size will require great care in filing and use to avoid bending. A plan recommended by Mr. Gray is to file up a bell-metal polisher about ⅛th of an inch thick, and of the required width, and to tin the face with a copper bit, muriatic acid and solder, and making a mould for half the length of the polisher in plaster of Paris, cast on a layer of grain tin, previously heating the bell-metal to rather more than the melting point of tin. A polisher made in this way is far lighter and more rigid than any solid tin one. Circular blocks should be cast with a flange on the bottom, and considerably thicker than required. By means of the flange you can grip them in the mandrel and surface them, taking a considerable portion off the top. If there are impurities and

ately sharp red stuff, using a slightly circular stroke. Instead of a plain cork some finishers use a hemisphere of cork resting in forks cut in another cork as in Fig. 59. When quite flat and smooth the wheels are washed in soap and water and burnished on a clean hard cork with a burnisher well rubbed on a board with rotten stone or red stuff. To ensure success in polishing wheels the greatest cleanliness must be observed, and the polisher frequently filed to keep a flat clean surface. If the operator cannot get on after a little practice failure can generally be traced to a want of the scrupulous cleanliness absolutely necessary throughout the operation. In fixing the escape wheels to the brass block there must be but a smear of resin ; too much will be fatal. A mixture of equal parts of beeswax and resin is preferred by some as it has the advantage that it may be removed from the block with hot water.

Large Steel Pieces, such as indexes and repeater racks which are not solid, and springs should be shellaced to a brass block and polished underhand ; a flat surface is first obtained by rubbing with fine emery on a glass plate ; afterwards with coarse red stuff on a bell metal block. The work is then finished off with diamantine on a zinc or grain tin block. The diamantine should be well beaten up on glass with as little oil as possible. Such parts as rollers and collets are polished in the same way. Levers are pressed into a piece of willow held in the vice and polished with a long flat bell metal or zinc polisher, moving the polisher instead of the work. There is nothing like diamantine for giving a good black polish. It is, however, very quick in its action and requires some little experience to avoid overdoing it and making the work foxy. The work, polishers, &c., must be kept scrupulously clean.

Pinion Leaves may be polished by means of a tool, as shown in Fig. 60, which consists of centres for holding the pinion and guides through which the runner carrying the polisher works. The polisher is of some soft material, usually lead. Where pinions are made in large quantities different methods of polishing are adopted. Lancashire pinion makers use a swing polisher suspended from the ceiling.

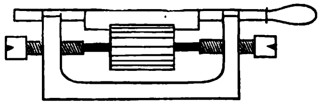

Fig. 60.

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grit in the metal, they have a tendency to rise to the top and are thus removed. Tin, previous to being cast into blocks, &c., should be carefully melted several times in a *clean* iron ladle, and each time poured from a height while in a melted state into water, thus breaking it up into very small particles, and enabling you to wash it thoroughly to remove all grit, &c. The file use for finishing the face of tin polishers should be an old smooth-cut one *well worn.* A new file is useless for this purpose, as it clogs and cuts, leaving deep scratches in the metal. The file marks should be stoned out, and finally the face carefully burnished with a flat burnisher.

Facing Pinions.—The facing tools should be made of steel to be used with coarse stuff for squaring up the face, and bell-metal with diamantine for finishing. The pinion arbor must have only moderate play inside the tool, but its *end* must be kept perfectly free, or the points of the leaves will not come *up*. To ensure this freedom the tool should be drilled from the back with a large drill, so that the smaller part of the hole shall not embrace more than half the length of the pinion arbor. Convenient tools may be made by providing a tube of a proper size tapped on the inside, into which stoppings of steel or bell-metal (to form the facing tool) are screwed. This plan has the advantage of giving ample play to the end of the arbor, and the polisher when worn out can be easily renewed. To face pinions one end is supported against the back centre of the turns, and the pinion rotated by means of a screw ferrule and hair bow (see Fig. 61). The tool is pressed against the pinion with the end of the fore-finger, and the bow held at the *top*, moved with long steady strokes. The tool must be kept flat by frequent filing, care being taken to keep it upright, so as to present a true face to the work. If it gets out of truth it should be put on an arbor and turned true. When the tool is of a proper size the pinion will "speak" (make a squeaking noise) as the red stuff is drying off; if it does not speak it may be taken for granted that something is wrong, most probably an improperly sized or badly shaped tool. The steel tool should be used till the face is quite square at the ends and sides of the leaves and with the ring well formed at the bottoms. Before finishing with the bell-metal tool, the pinion must be thoroughly cleaned with bread and by a peg being passed through it, so as to remove all dirt. The hole in the tool must also be cleaned in the same way. In finishing, the tool must be filed with a very old smooth cut file, or rubbed with a water of Ayr stone, and only slightly damped with diamantine. The bow must be moved smoothly and steadily; if a jerky motion is given to it perfect flatness of the face will not be attained. For a similar reason the finishing should be very quickly done, for if the tool is at all worn the face will be rounding.

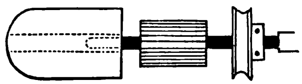


Fig. 61.

Fuzee Hollows may be polished with a cup-shaped polisher made of iron or sheet copper and held in a pair of clams. The tool is made by first stamping the cup in a die, a hole of the proper size is then made in the centre of the cup, and the tool, held by the sides is slightly turned in the mandrel to true it. The inside of the cup must also be chamfered a little to give the tool effective play behind the fuzee shoulder. Care must be taken to turn the hollow of a proper shape, not too deep, and to give the requisite concave form the edge of the graver should be curved on the oilstone. The fuzee pivot is supported against the back centre of the turns, the clams held in the left hand, and the fuzee revolved with a bow. After turning the hollow the tool must be tried with a little red stuff, and if it does not touch the hollow all over that part or parts of the hollow touched by the tool must be again turned slightly. This must be repeated till the hollow fits the tool exactly, when but very little polishing will be required. When the tool fits the hollow properly it will speak in the same way as a pinion during the process of facing. When the hollow is smooth from coarse red stuff, it may be finished with fine red stuff or diamantine. If the hollow should have a milky appearance from the fine red stuff, it may be improved by rubbing it with a clean peg and clean fine red stuff mixed wet. Set-square hollows, and the hollows of centre pinions may be polished in similar manner. Since the introduction of diamantine the hollows of small pinions are often polished IN the turns with a small zinc polisher held in the fingers, which quickly accommodates itself to the shape of the hollow, or a bit of copper wire filed to the proper shape may be used in the same way with fine diamond powder.

For Solid Faced Pinions, barrel arbor shoulders, the backs of rollers and the like the work is fixed in a swing tool of the form shown in Fig. 62. The work to be polished is mounted on an arbor which is held between the screw centre at bottom and the runner

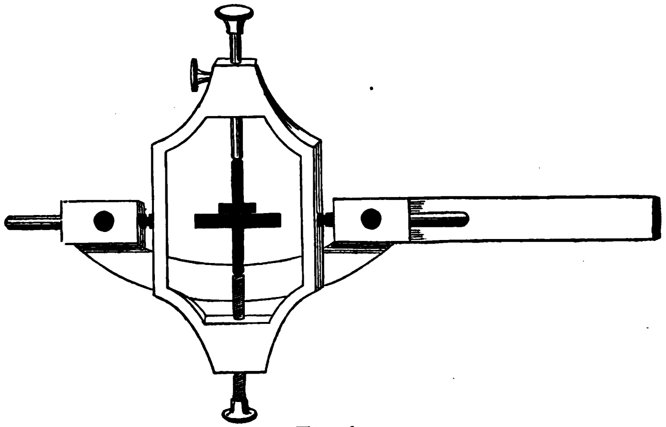


Fig. 62.

at the top of the tool. The face to be polished must be exactly level with the horizontal centres of the swing tool, or the work, instead of being flat, will be rounding. Sometimes this swing tool is held in the turns, but it is preferable to have a frame as shewn in the sketch, which allows free motion of the polisher. The end of the frame is held in the vice. The arbor on which the work is mounted must run freely in the centres of the swing tool, so that the motion of the polisher causes the work to rotate; at the same time the arbor must have no shake. The proper adjustment of the arbor between the centres must be seen to occasionally during polishing.

Lever Edges, Chronometer detents and many other parts are polished in a swing tool, like Fig. 63, care being taken as in the previous case to get the surface to be polished level with the swing-

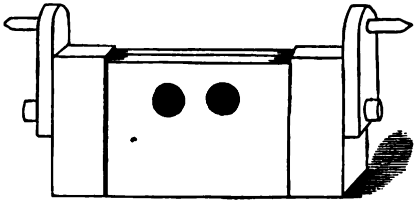


Fig. 63.

ing centres. The teeth of chronometer escape wheels are also polished in a very similar swing tool, each tooth in succession being brought to the swing level.

Roller edges for Lever and Chronometer Escapements are often polished by means of a revolving disc or mill of bell-metal. The roller on an arbor is fixed to the slide rest of the lathe in a pair of turns or specially adapted holder as shewn in Fig. 64. When brought into contact with the mill it is gently turned with the thumb and finger, and the slide rest traversed the while so as to move the roller in a plane parallel with the face of the mill. After the edge is polished if the corners of the roller are to be chamfered the holder is turned first one way and then the other to an angle of 45°. Another way of polishing roller edges is to place the roller to be polished on an arbor between two flint hard rollers of the same diameter as the one to be polished is to be when finished, and polish in the turns. Yet another way of finding a rest for the polisher is by means of a broad headed screw put through the runner of the turns, the roller is placed near the end of the arbor and varying diameters are accommodated by raising or lowering the screw.

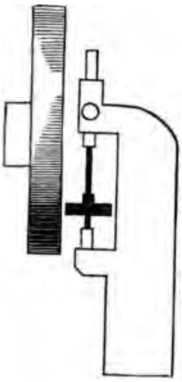


Fig. 64.

Stud Holder.—Fig. 65 is a little holder for studs. It turns on a universal joint at the bottom, so as to bring all the angles of the stud in turn within range of the polisher, which works to and fro on a steel rest attached to the body of the tool with screws for tightening the joint in both directions if it is not stiff enough. For watch studs of steel the jaws of the holder are of brass; for chronometer studs of brass they are lined with ivory.

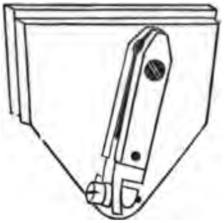


Fig. 65.

Polishing Screws.—Finishers generally nse the old English screw head tool for producing the beautiful "tallow top" screws used in English work. This tool is a mandrel running in one bearing with an overhanging ferrule and a rest for the polisher, like Fig. 66. The screw whose head is to be polished is screwed into a chuck, of which there must be a sufficient variety to suit all of the ordinary run of screws. Tool marks are usually first removed with a slip of oilstone, and the polishing finished with red stuff or diamantine. A chuck like Fig. 67 is used for polishing the taps and points of the screws. Here the screw is slipped into a hole in a narrow-faced "lantern" from the *back*, and kept in position by a screw which runs through the boss of the lantern and jambs the screw head against the back of the face. With a long bow screws are polished very expeditiously in the English tool, but it is not so handy for jobbing where so many different kinds of screws are met with.

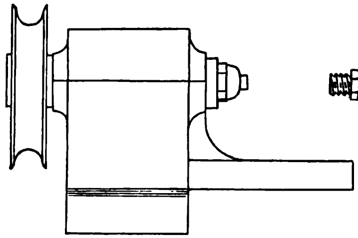
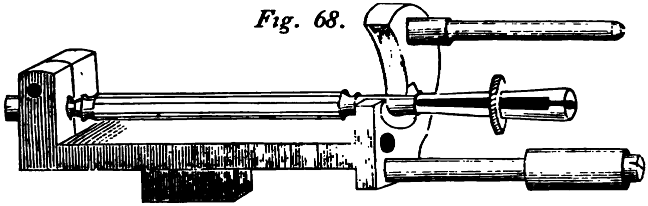


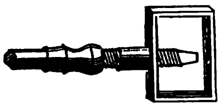
Fig. 66.

Fig. 67.

For jobbing the Swiss screw head tool as shewn in Fig. 68 is generally used. There are a number of different sized holders lined with brass so as not to bruise the taps of the screws. It is important to use one of the right size, for if too small in the hole the screw is sure to be marked. The holders are sprung open, and a sliding thimble serves to nip them together sufficiently to grip the screw to be polished. The holders are rotated by rubbing the palm of the left hand to and fro over the octagonal body. The polisher rests on a roller to permit of smooth running. The upper arbor seen projecting from the body of the tool is to receive a lap, which is pressed against the work and slightly rotated to and fro by the thumb and finger of the right hand, while the work in the holder is rapidly rotated with the left. Two nearly semi-circular laps are generally screwed into one holder, as shewn in Fig. 69, one of soft steel and the other of gun-metal. Fig. 70 shows a lantern for polishing the ends of fusee squares. Smaller ones of the same kind are used for holding screws so that the taps and points may be polished as described in speaking of the English tool.

Fig. 68.





Fig, 70.

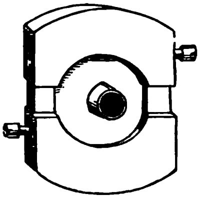


Fig. 69.

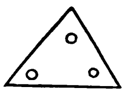


Fig. 71.

Fig. 71 is a little triangular plate used for polishing screw heads flat underhand. In two of the holes are screws with hardened points, and in the third, head downwards, is the screw to be polished.

Conical Pivots.—The cone should be an easy curve dying away into the pivot proper, which runs into the hole ; this part must be perfectly straight and parallel. The pivot having been turned to a little over the required size, its end is laid on a bed formed in a runner of the turns. Every time the work is examined the bed of the runner must be cleaned and the runner adjusted to a slightly different length so that it does not bear on the same part of the pivot. If this is neglected the pivot is sure to be marked. A soft steel polisher made to suit the pivot as shewn in Fig. 72 is then used with either oilstone dust or red stuff. It should be used with a backward and forward as well as a rolling motion till the pivot is reduced so that it will just fall off the hole. The pivot is then finished with a very smooth burnisher and oil. Instead of the soft steel polisher some prefer to use a hard steel burnisher roughened on a piece of lead with emery. which makes an equally good pivot. For rounding the end of the pivot a thin edged runner to allow the end of the pivot to

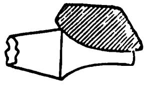


Fig. 72.

come through is used. The pivot is rounded by passing the burnisher over the end *downwards*. If used upwards a burr may be formed. There is a little difference of opinion as to the proper shape for the ends of balance staff pivots. Many manufacturers say the watches time better if the ends are left nearly flat, as shewn in Fig. 72. This is not accepted by others, who prefer the pivot ends left rounder.

The size of the ferrule is not a matter of indifference. While a large size is an advantage in facing a pinion, as small a one as possible should be used in polishing a pivot. The chief difficulty of beginners is to get the polishers and burnishers of exactly the same shape from end to end so as to follow each other properly. This uniformity may be secured by drawing the polishers and burnishers from end to end across a piece of hardened steel, the edge of which is of the shape it is desired the pivots should be shaped, till they coincide with the form of the steel (see Fig. 73). The best plan is to file up two pieces of steel together, slightly bevelling the edge of one to give it a cut, and leaving the other quite square. With only one piece there is a tendency to cut the polishers too deeply, leaving them ridgy.

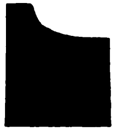


Fig. 73.

Straight Pivots with square shoulders are polished with a steel polisher slightly curved along the edge that acts against the shoulder of the pivot, as shown in Fig. 74. This edge is also dovetailed a little so as to form rather less than a right angle with the bottom of

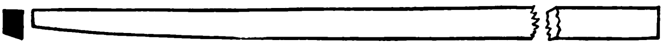


Fig. 74.

the polisher in section as shown in black at the left hand of the figure. The operator will find by experience the amount the polisher requires to be curved. It is rarely that one man can use another's polisher so well as his own. If the edge of the polisher is too much dovetailed it will produce a wavy shoulder to the pivot. The pivot must be turned nearly to right size, and the shoulder quite square. During polishing the *end* only of the pivot must rest on the end of the runner. A piece of paper may be plaeed underneath the pivot to reflect the light. The light so reflected must be divided equally on either side of the shoulder during the process of polishing, and uniform pressure exerted along the pivot. The polisher must be used with a backward and forward motion, and with a slightly lateral motion also to prevent ridges being cut in the pivot.

Snailing.—Fusee caps, steel keyless wheels, &c., are snailed with a copper mill like Fig. 75. The face of the mill is hollowed out, leaving only a thin projecting rim. The work to be operated upon is placed so as to work just freely between the centres of a pair of turns, the rest of which has been removed from the holder. There is projecting from the snailing mill a foot which fits the holder of the turns, so that the mill and the turns may be attached to each other, and by means of the screw in the rest holder adjusted at any required distance. The edge of the mill is then brought into contact with the face of the work, the mill being slightly angled so as to touch on one side only. The snailing mill is fixed in nearly the right position in relation to the work and the final angling made by moving round the runner of the turns, the arbor of the work being centred near the top of the runner. As the mill is rotated the desired curves are produced on the surface of the work, the mill being charged with fine "double washed" emery at first, and sharp red stuff for finishing off. For brass a bone or ivory mill is used with oilstone dust first and redstuff for finishing off. Fine redstuff is not suitable. Snailing requires a sharp polishing material or else instead of distinct curves the surface will become quite smooth. A long bow should be used to rotate the snailing mill. At first the curves will be rather undecided, but if the mill is set at the proper angle it will not slip on the surface of the work and will soon produce a nice curve. The last stroke or two should be given downwards, the bow being bent and relieved as it comes to the end of the stroke.

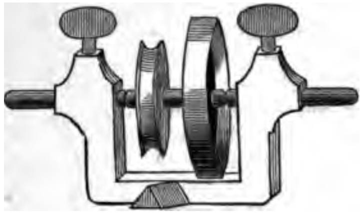


Fig. 75.

Frosting Steel Keyless Work.—After the work has been prepared with a surface free from scratches it is rubbed with a short backward and forward motion on a small glass slab with a thickish paste of oilstone dust and sweet oil. Before mixing this paste look over the pounded oilstone with a very strong magnifying glass and carefully remove all the black atoms which if left would inevitably scratch the work. The work is cleaned and finished by rubbing in a circular direction with pith, or instead of rubbing with pith the work may be carefully breaded and immersed in benzine.

Clock Plates.—Plates for carriage and other small clocks after being stoned flat are polished with a willow polisher and either rotton-stone or oilstone dust and oil. Chronometer plates are polished in the same way and afterwards with redstuff and oil.

Spotting.—Chronometer and occasionally watch plates are spotted with a tool like Fig. 76. The plate is fixed to the top of a slide rest and the marks are made with a small bone or ivory revolving spotter and a very little diamantine. The spotter is sometimes hollow but more generally solid and set eccentrically. A hollow spotter soon gets choked up with polishing stuff and on the other hand an eccentric one is apt to get broken when a spot is partly over a hole in the plate. A spiral spring round the arbor of the spotter keeps it off the work and a little pressure on a knob at the top brings the spotter into action. About one stroke with a bow revolves the spotter sufficiently for each spot. The pattern is made by turning the handle of the slide rest equal amounts after each spot till a row is finished, and then moving the transverse slide an amount equal to the pitch of the pattern.

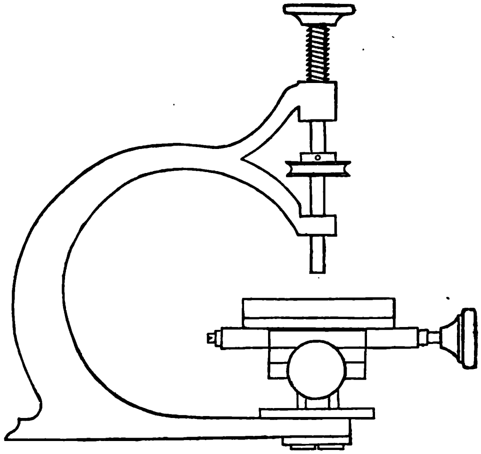


Fig. 76.

Diamond Mills.—For cutting and polishing ruby pallets and other hard stones discs charged with diamond powder and revolving at a high speed are used. The cutting mills are of soft copper about an inch and a half in diameter into which diamond powder of a coarseness suited to the work has been hammered. Polishing mills are usually of ivory or tortoishell and very fine diamond powder is used loose instead of been beaten into the mill. Vegetable ivory is now generally preferred. Being slightly porous it takes the diamond powder better and polishes quicker. The diamond powder for charging the mills is graded by pouring it into a vessel containing olive oil and allowing it to settle. The finer diamond powder is then poured off with the oil and the coarser remains at the bottom of the vessel.

Diamond and Sapphire Files.—A diamond file is formed of a strip of copper with diamond powder hammered into it. A sapphire file, which is useful for operating on garnet and other soft stones, is made of a piece of sapphire which is flattened down on a diamond mill and shellaced to a brass handle. The file is rendered coarser or finer according to the coarseness or fineness of the mill upon which it is flattened. A file too coarse used for the corners of garnet pallets or other fine edges would be liable to chip the stone. The corners of garnet pallets may be reduced with a strip of copper and diamantine if a sapphire file is not to hand.

The Depthing Tool.—Running Depths.

The use of the Depthing Tool shown in Fig. 77 is to ascertain the proper working depth of a wheel and pinion, and to transfer their distance of centres to the plate of a watch or clock.

Accuracy of construction is absolutely essential in the depthing tool, and before venturing to use a new one it should be tested. The centres should be turned end for end and transposed, ascertaining after each change if there is any deviation in a circle described by the points; also if the points when they meet exactly

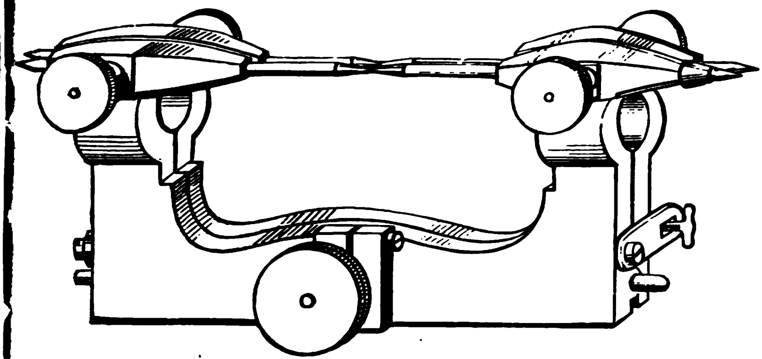


Fig. 77.

coincide. If possible a comparison should be made with an approved tool by trying in both a large and also a small wheel and pinion. The adjusting screw had better be removed so as to see that the joint works smoothly, and that the spring has perfect control over it. If the joint is stiff and appears to be dirty, the joint pin may be taken out and the joint thoroughly cleaned.

In use the depthing tool is held in the left hand, with the adjusting screw for opening and closing the tool pointing to the right. After making sure that the points on the ends of the pinion are true it is carefully placed face uppermost in the centres on the left. The tool is opened sufficiently for the teeth of the wheel to clear the teeth of the pinion, and the wheel is then put in. By means of the regulating screw the teeth of the wheel and pinion may be brought into contact, taking the precaution to feel with a finger of the right hand that they do not butt while coming together, or a broken pivot may be the result.

When the teeth are in contact both the sliding centres of either the wheel or pinion may be loosened and pushed up by the bottom centre or down by the top centre as may be required, in order to get the faces of the teeth level so as better to observe the depth. The faces being level, and the bottom centre of the pinion tightened the top centre may be loosened and pressed against the board until the pinion runs sufficiently friction tight for the shake of the wheel teeth in it to be felt, and then secured with the nut.

Now the tool is held up to the light, the wheel turned by the forefinger, and while looking through the wheel and pinion they are brought into depth by means of the adjusting screw. If the pinion has straight cut leaves the shoulder or beginning of the rounding of a wheel tooth should come into contact with the shoulder of a pinion leaf when the two make parallel lines as in Fig. 78; but if it is what movement makers call a bay-leaf pinion the pinion line will be angled a little towards the centre when the shoulders come into contact. It is important to see that the engaging contact is at the shoulders, for if it is on the roundings of the teeth a butting action ensues. The shake is then to be tried. It is not sufficient to see that there is freedom in one position of the wheel and pinion; the pinion should be moved round by minute portions so that it can be ascertained whether there is proper shake from the time of first contact till the leaf leaves the wheel.

Fig. 78.

Butting is generally indicative of a pinion too large. If the excess is not very great it may be got over by slightly increasing the depth; but a large pinion is a bad fault, for with it far too much of the action is before the line of centres. Pinions of less than ten leaves may with advantage be rather under-sized so as to bring the action more after the line of centres. A pinion must not, however, be so small that the wheel tooth drops from leaf to leaf, although if this fault is not of large extent it may be corrected by altering the shape of the wheel teeth so that the rounding or shoulder is carried more towards the root of the tooth without shortening the tooth (see Fig. 79. The original shaped tooth is shown on the left and the altered shape on the right. The running of an under-sized pinion will also be improved if the depth is made a trifle shallow.

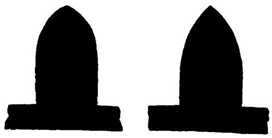


Fig. 79.

Being satisfied that the depth is correct, that there is proper shake and no butting the depth may be marked off. For this purpose the binding nuts are loosened and the wheel and pinion taken out of the tool. Then while one centre is kept tight the tool is held upright with the tight centre in the hole from which the depth is to be marked, and the loose centre is brought down until it touches the plate. Some caution must be exercised, for with a jewelled hole it occasionally happens that a beginner cracks the jewel in getting the centres to height. Great judgment and care are required to ensure the perfect uprightness of the tool, and if it is out in the slightest degree the depth will not be marked off as it was adjusted in the tool. The centres should be fixed, and as they rest on the plate the tool observed critically all round ; if the smallest deviation from the upright can be detected the tool should be reset till it is correct. When it is right a portion of a circle is lightly marked across the line where the wheel or pinion is to be planted. Watch plates are marked by holding the tool still and turning the plate. A drilling centre is then marked on the depth line with a pointed drill or chamfering tool. This operation, too, requires considerable skill, as does also the drilling off for, however carefully the depthing may have been done, the slightest deviation by the drill either in centring or drilling will turn a well-marked depth into a bad-action one. The drilling of the hole perfectly upright, too, is essential for a correct depth. Sometimes a table tool is used to ensure straight holes, or they are drilled in the mandrel, but a skilled workman will drill them in the ordinary way to a certainty. A beginner should certainly use the mandrel. It is better after centring the plate and catching a centre by means of a graver to reverse the plate in the mandrel and drill from the original mark on the other side for, although the plate may be set true with the pump centre, it is liable to be drawn a little in fixing, and in a small watch extreme accuracy is desirable. Having drilled the bottom hole a round broach should be passed through it to remove all burr and a long peg cut to fit the hole. The rest of the mandrel is then brought up almost close to the plate so as to support the peg, and keep it from turning. Now, as the mandrel is rotated, the slightest want of truth in the hole will be indicated by a movement of the free end of the peg, and the plate must be shifted till the free end of the peg has no motion whatever. Then the upper plate can be fixed and the top hole drilled, and its uprightness tested in the same manner.

The Rounding-Up Tool.

This most ingenious tool shown in Fig. 80 is one of the most useful to watch jobbers. By its aid a wheel may be almost instantly reduced in diameter; corrected if out of round, or have the form of its teeth altered as may be required.

The cutters are a little over half a circle and terminate in a guide. While one end of the guide meets the cutter the other angles a little, so that instead of meeting the other extremity of the cutter when the circle is completed leaves a space equal to the pitch of the wheel to be cut. By this means after the cutter has operated on a space the wheel is led forward one tooth by the time the cutter arbor has completed its revolution.

Some little practice is required to select exactly the cutter required. Care must be taken not to use one too thick or the teeth will of course be made too thin, and the wheel probably bent. When the guide is adjusted to the pitch it will be well to see that

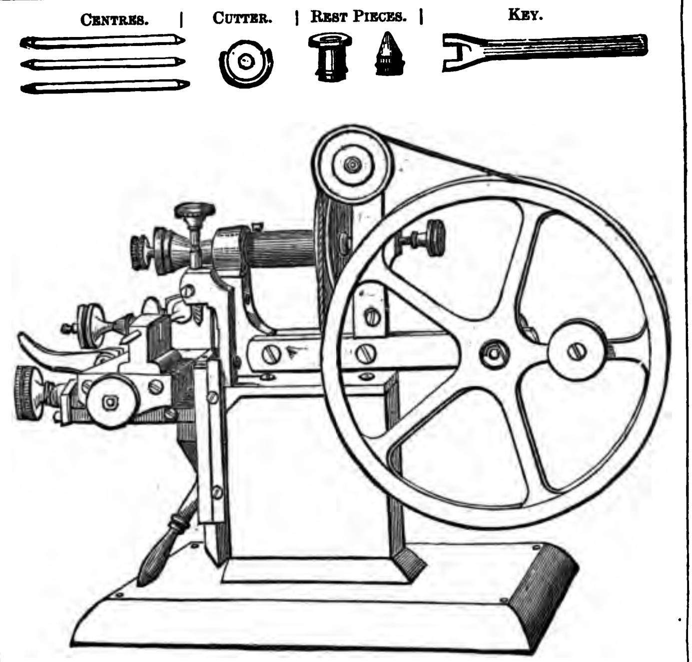


Fig. 80.

it enters the space properly before rotating the tool quickly. The wheel should be fixed firmly but not too tight between the centres, which should rest well on the shoulders of the pinion. The rest piece for the wheel should be as large as possible to keep the wheel from bending, to give it firmness, and to ensure a clean cut.

Ingold Fraises or Cutters.

These consist really of hardened pinions with square sharp points. The fraise is gradually brought into depth in a specially arranged depth tool, with a wheel whose teeth are incorrect and rotated the while by means of a ferrule and bow. The fraises do not supersede the Rounding Up Tool, but may often be used after it with advantage, for if a wheel contain any thick teeth they would not be corrected in the Rounding Up Tool which also of necessity leaves the teeth slightly hollow. The fraises cut the teeth in the direction they move on the pinion in working, and therefore leave a surface which works with the least friction.

A fraise for any particular wheel should be chosen so that when placed upon the wheel the fraise does not bottom, but just touches the sides, and almost closes over the middle one of the teeth engaged at the same time just making contact with the teeth right and left. If, the fraise chosen is too large, it will cut a jagged and uneven tooth; and, if too small, will leave a ridge or shoulder on the tooth; in this, as in everything else, practice makes perfect. As a guide at first, it will be prudent to use the sector to ascertain the most suitable fraise for use; thus—place the wheel to be operated upon in the sector, and choose a fraise of such a size as will correspond, not to the size indicated by the number of its teeth, but to *two teeth less*.

The Mandrel.

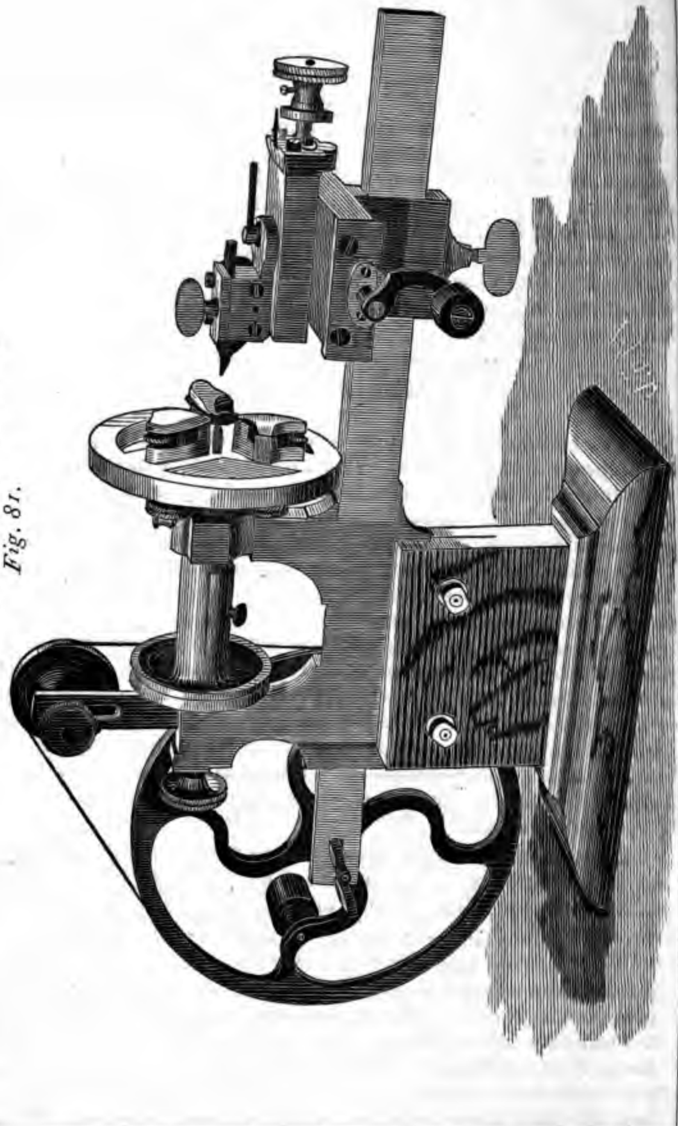
A good Mandrel with slide rest is one of the most perfect tools a watchmaker can possess. The English and Swiss tools have each advantageous features. The English head is generally crossed out, and the mandrel is worked by means of a hand wheel and gut giving an easy silent motion, superior to the Swiss wheel and pinion action. On the other hand the Swiss slide rest is better than the English, The Swiss get the best effect by forming their dovetail at an angle of 45°, while ours are a great deal too upright. The Swiss slide rest main screw is finer-cut and has a projecting end with an adjustable stop for precise turning. The slides, too, are all adjustable, and the main slide is turned upside down, so that it can be capped to keep the dirt out. The Swiss meeting centre is also a great convenience in centring work from the front when the pump centre is not available. Bnt perhaps the greatest convenience of all in the Swiss tool is an arrangement on the slide rest whereby the cutter can be raised or lowered.

Fig. 81 is copied from a tool lent to me by Messrs. Grimshaw and Baxter, and seems to combine the advantages of the English and Swiss styles. The head is crossed out, and the driving wheel most conveniently placed. I have not thought it worth while to reproduce the meeting centre and hand rest.

In choosing a mandrel see that the slide is free from end shake throughout its entire range, and then observe if the oil on the dovetail reproduces the pitch of the screw; if it does it is a sure sign that the screw is not true, but "drunk" as it is termed. See that the pump centre is free from shake, works easily in and out, and coincides with the meeting centre. Then carefully upright a high

Mandrel and Slide Rest.

Fig. 81.



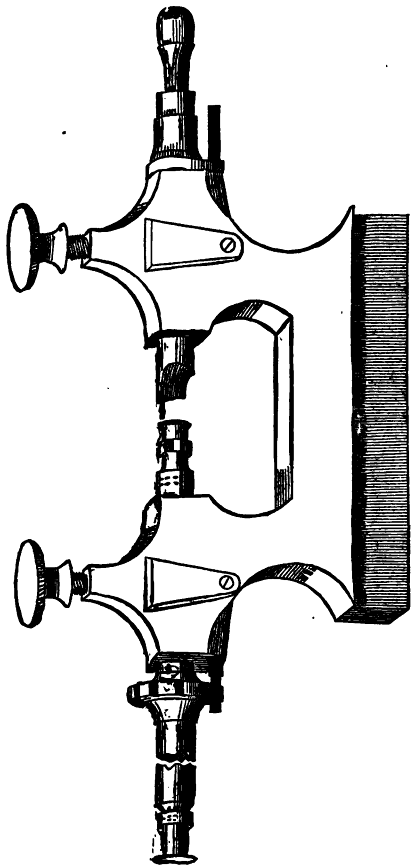
pillar frame, and when it is correct turn it in the rings first a quarter and then half-way round testing it for upright after each change. Then upright a third wheel where a bar is used, and having removed the screws from the bar put it in the tool upright and push the bar off, and see if the pump centre is correct with the upper hole. When satisfied on all these points examine the bearing for shake and smooth working, and you will be in a position to decide if you have a good tool or not.

To use the tool make a good pointed cutter, leave it quite hard and gloss it, buff the extreme sharpness off the cutting edges and proceed to turn as large a sink as possible on a flat piece of brass; having turned the sink make the cutter take the lightest possible cut, rotating the mandrel wheel as fast as convenient while you screw the cutter very slowly across the face of the sink. This should give good work without polishing, and as a further trial rub it with a piece of flatted slate pencil wetted on the tongue when a rub or two ought to take all cutter marks clean out. If the screw pitch is repeated on the sink it indicates a bad tool. By varying the shape of the cutter what at first sight seems inaccessible places may be got at. It is always well to consider if it is possible to shape a cutter to compass a difficulty, and with a stock of cutters it is surprising what a number of things can be done with a mandrel. As a rule pointed cutters suit watchmakers best. Watchmakers' tools are not so solid, and the fittings so rigid and free from vibration as to make it practicable to turn with a flat faced cutter, but a partially flat cutter like the sketch turns very clean; the flat of the cutter must always be level with the centre of the mandrel, and when it wants sharpening whet the sides, merely polishing the top. The front of the cutter is often by beginners formed to make too acute an angle with the top. The front should only be ground back sufficiently to just clear the face of the work.

The Jacot Tool.

In almost every watch repairing job, the pivots require re-burnishing, and although some English jobbers stick to the turns it is generally admitted that by means of the Jacot Tool represented in Fig 82, pivots can be more easily and quickly renovated. The burnisher being supported parallel to the axis of the pivot it is impossible to make the pivot smaller at one end than the other, which is very often the case when pivoting is attempted in the turns by the ordinary run of jobbers. In experienced hands the use of the Jacot Tool is not confined to restoring pivots. An expert workman will, with the use of the file and a couple of burnishers—one coarse and the other fine—form and polish a pivot from the solid arbor with ease. This of course is an achievement not to be attempted by a beginner.

A new tool should be taken apart and thoroughly cleaned before use in case of emery or grit having been left in it. To ensure absence of all burr, which would scratch the pivots, the beds should be polished out with boxwood and diamantine. In the very finest



Jacot Tool.

Fig. 82.

tools the beds are jewelled, and then, of course, this precaution is unnecessary. The face of the lantern or disc with holes for rounding up pivots should be polished and the holes also by means of a fine wire polisher. Some watchmakers remove the lantern altogether and substitute one of German silver as being less likely to scratch the pivots.

Fig. 83 is a section of the burnisher used for straight pivots; Fig. 84 that for conical pivots; Fig. 85 is suited for cutting back shoulders; and Fig. 86 for rounding off pivots. Burnishers for conical pivots are of course varied in form to suit different shaped pivots. The angles shewn are adapted for use when the operator works at the Jacot Tool cross-handed as foreign watchmakers do. Many Englishmen work right-handed, and in that case the angles are reversed.

Fig. 83. *Fig. 84.* *Fig. 85.* *Fig. 86.*

The greatest care should be taken of the files and burnishers used with the Jacot Tool. They should have thin and light handles and be kept in paper cases to avoid contact with other tools on the board or they will soon become notched. *Thin* oil should be used with the burnisher. Its action is then more sensitive to the touch than when thick oil is used.

Sliding Carrier.—This useful adjunct, though not generally supplied with the Jacot tool, may with advantage be fitted to it. It is often handier than the screw ferrule and saves time when used instead of waxing or shellacing. A small steel plug or arbor is fitted to one of the centres as shown (Fig. 87). The ferrule of steel runs on a collet of hard brass and is kept in its place by a small washer. The collet is pierced to move freely on the steel arbor and its projecting end slit and then pinched together so as to grip the arbor sufficiently tight to remain in position when in use and yet not so tight but that it may be moved to and fro without trouble. Holes may be made at convenient positions in the ferrule to receive the carrier pin. The shake between the crossings is not objectionable with small sized wheels, but for large and heavy balances, &c., two pins and a larger ferrule may be used. To compensate for the room taken up by the projecting end of the collet a little is sometimes taken off the boss of the Jacot tool.

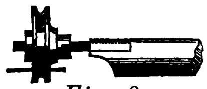


Fig. 87

Spring Ferrule.—This is a convenient form of ferrule where there is but little room. As shown in Fig. 88 a saw slit is made across the ferrule to meet a hole drilled through it. The larger this hole is the more springy and better the ferrule will be. But if it is desired that the centre hole should be large enough to take the body of the pinion then the outer hole must be reduced in proportion.

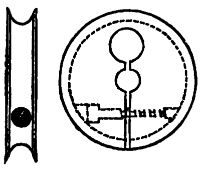


Fig. 88.

Cylinder Height Tool.

This is a useful tool for measuring cylinder heights from the plate and for taking other vertical distances of escapements. It consists of a jaw fixed to a brass tube and a similar jaw free to move up and down. The brass tube is slit to receive the extremity of the moveable jaw, which is fixed to a nut fitted into the tube. The nut terminates in a long steel pivot small enough to enter a watch jewel hole. When the jaws are closed the pivot is just flush with with the nose of the tool, consequently the distance it is projected beyond the nose of the tool is exactly represented by the distance of the jaws apart. In addition to the screw with the milled head for opening and closing the tool there is sometimes a set screw at the side for securing a measurement.

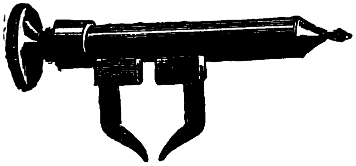


Fig. 89.

Self-Centring Chucks.

One of the most useful lathe attachments is what is known as an American chuck, which opens and closes concentrically. Chucks of this kind were made here many years ago, though the credit of a most important improvement in the method of gripping the work, which is worth description, is, I believe, due to the American Watch Tool Company; at all events it is taken from one of their lathes. Fig. 90 is a longitudinal section of the upper part of the lathe head. **A** is the chuck, which terminates with a screw. The mandrel, **B**, is hollow, and contains a barrel through which also a hole is pierced. At one end of the barrel is a female screw to match the screw on the chuck, and at the other end a small hand wheel **C**. By turning the hand wheel so as to screw the end of the barrel on to the chuck, the chuck, which is slit crosswise, is drawn further into the cone of the mandrel and contracts, thus gripping the work. There is a feather in the straight part of the mandrel hole to prevent the chuck turning round.

Figs. 91 and 92 show two of the chucks, one for wire and the other for wheels.

Self-Centring Chucks.

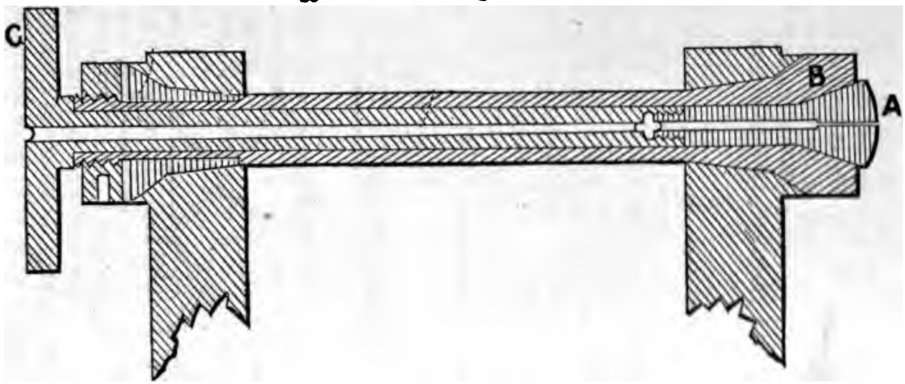


Fig. 90.

Fig. 91.

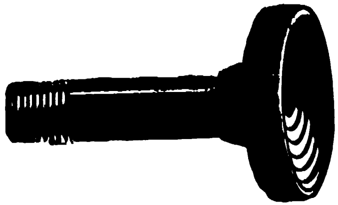


Fig. 92.

Pinion Height Tool.

This (shown in Fig. 93) is very similar in construction to the Cylinder Height Tool, except that two feet are substituted for the single pivot. The exact distance between the jaws corresponds to the exterior measure of the feet. If, therefore, the tool is adjusted so that the feet pass freely between the plates, or the plate and the bridge, the exact length of pinion is represented by the opening between the jaws.

Fig. 93.

Watchmaker's Turns.

Everyone who knows anything of watchmaking is tolerably conversant with the common turns shown in Fig. 94. They are used for turning arbors, pivotting generally, and other purposes. To make the best use of the tool a good stock of runners is a necessity. Steel runners with male centres are handy when turning bouchons or other hollow pieces. Brass runners are used for polishing pivots

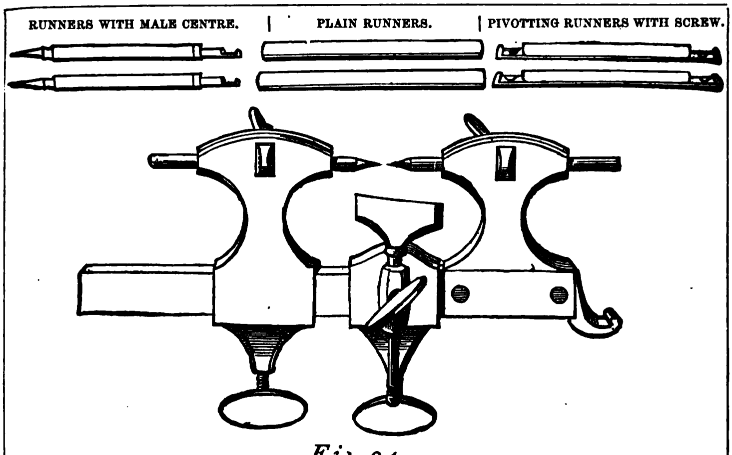


Fig. 94.

on, and for repolishing pivots that have become marked some watchmakers use an ivory bed. Sometimes a broad headed screw is used on the pivotting runners as a support to the polisher. Thin edged brass runners with small holes through which the pivot projects are used for rounding pivot ends. A runner with a hole in the edge large enough to allow the pivot to enter up to the cone is used to support the pivot while burnishing on a balance.

New Pivot.—The best and simplest device for centring and drilling up an arbor to receive a new pivot is a runner as shown in section in Fig. 95. It is a steel runner accurately fitted to the turns and pierced throughout its length. The hole is tapped at one end to receive a bush with a trumpet-mouthed hole. The arbor to be drilled for a new pivot is placed in the turns with the shoulder to be drilled resting in the trumpet mouthed runner and the other end centred exactly opposite. A drill stock having on it a ferrule is fitted to the hole in the runner, and the hole is drilled from the *back* of the turns. Two or three of the little trumpet mouthed bushes should be provided for different sized pivots. By adopting this method the arbor is centered at once and the hole is bound to be true throughout its length. A chisel shaped drill should be used. After hardening the drill by flaring it in the air it should be let down all but the extreme cutting edge. For this purpose catch the point in a pair of plyers and then hold the drill in the flame of a lamp till the temper is lowered sufficiently, when plunge it into oil. The plyers preserve the point quite hard.

Fig. 95.

Jewelling Tool.

Watch jobbers often find it handy to have tools to raise a jewel setting in order to replace a damaged hole, and to burnish the setting over again. The points of Fig. 96 are for lifting the setting, the tool being rotated between the finger and thumb, and the points opened by means of the screw as may be required. For rubbing over the setting again a tool with he points the reverse way is used.

Fig. 96.

To Calculate Clock Trains.

Divide the number of pendulum vibrations per hour by twice the number of escape wheel teeth, the quotient will be the number of turns of escape wheel per hour. Multiply this quotient by the number of escape pinion teeth, and divide the product by the number of second wheel. This quotient will be the number of times the teeth of second pinion must be contained in centre wheel.

For Example.—Take a pendulum vibrating 5,400 times an hour, escape wheel of 30, pinions of 8, and second wheel of 72.

Then $5,400 \div 60 = 90$. And $\frac{90 \times 8}{72} = 10$. That is, the centre wheel must have ten times as many teeth as second pinion, or ten times $8 = 80$.

The centre pinion and great wheel need not be considered in connection with the rest of the train, but only in relation to the fall of the weight, or turns of main spring, as the case may be. Divide the fall of the weight (or twice the fall, if double cord and pulley are used) by the circumference of the barrel (taken at the centre of the cord) ; the quotient will be the number of turns the barrel must make. Take this number as a divisor, and the number of turns made by the centre wheel during the period from winding to winding as the dividend ; the quotient will be the number of times the centre pinion must be contained in great wheel. Or if the numbers of great wheel and centre pinion and the fall of weight are fixed, to find the circumference of barrel, divide the number of turns of centre wheel by the proportion between centre pinion and great wheel ; take the quotient obtained as a divisor, and the fall of weight as a dividend (or twice the fall if pulley is used) and the quotient will be the circumference of barrel. To take an ordinary regulator or 8-day clock as an example—192 (number of turns of centre pinion in 8 days)$\div 12$ (proportion between centre pinion and great wheel) $= 16$ (number of turns of barrel). Then if fall of cord $= 60$ inches, $\frac{60 \times 2}{16} = 7.5$, which would be circumference of barrel at centre of cord.

If the numbers of the wheels are given the vibrations per hour of the pendulum may be obtained by dividing the product of the wheel teeth multiplied together by the product of the pinions multiplied together, and dividing the quotient by twice the number of escape wheel teeth.

Note.—A Table of diameters and circumferences of circles is given at pp. 91 and 92.

The numbers generally used by London clockmakers for clocks with less than half-seconds pendulum are centre wheel 84 gearing with a pinion of 7; third wheel 78 gearing with a pinion of 7.

The product obtained by multiplying together the centre and third wheels $= 84 \times 78 = 6552$. The two pinions multiplied together $= 7 \times 7 = 49$. Then $6552 \div 49 = 133.7$. So that for every turn of the centre wheel the escape pinion turns 133.7 times. Or $133.7 \div 60 = 2.229$ which is the number of turns in a minute of the escape pinion.

The length of the pendulum and therefore the number of escape wheel teeth in clocks of this class is generally decided with reference to the room to be had in the clock case, with this restriction, the escape wheel should not have less than 20 nor more than 40 teeth, or the performance will not be satisfactory. The length of the pendulum for all escape wheels within this limit is given in the table at page 90. The length there stated is of course the theoretical length, and the ready rule adopted by clockmakers is to measure from the CENTRE arbor to the bottom of the inside of the case in order to ascertain the greatest length of pendulum which can be used. For instance, if from the centre arbor to the bottom of the case is 10 inches he would decide to use a ten inch pendulum and cut the escape wheel accordingly with the number of teeth required as shown in the table. But he would make the pendulum rod of such a length as just to clear the bottom of the case when the pendulum was fixed in the clock.

In the clocks just referred to the great wheel has 96 teeth, and gears with a pinion of eight.

Month Clocks have an intermediate wheel and pinion between the great and centre wheels. This extra wheel and pinion must have a proportion to each other of 4 to 1 to enable the 8-day clock to go 32 days from winding to winding. The weight will have to be four times as heavy, plus the extra friction, or if the same weight is used there must be a proportionately longer fall.

Six Month Clocks have two extra wheels and pinions between the great and centre wheels, one pair having a proportion of 4½ to 1 and the other of 6 to 1. But there is an enormous amount of extra friction generated in these clocks, and they are not to be recommended.

Motion of the Earth Train.—As stated at page 12 the earth takes 365 days, 5 hours, 48 minutes, 49·7 seconds to perform its annual revolution round the sun. The following numbers will re-

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NOTE.—A full Table of ordinary trains, with length of pendulum, is given on page 90, and good examples of striking and quarter trains on page 116.

present nearly the motion of the earth, supposing the first pinion to turn in an hour, which it will do if placed on the centre wheel arbor of a clock.

Pinion, 8, 7, 7.
Wheels, 50, 69, 83.

Lunation Train.—The following numbers are suitable for a lunation train, *i.e.*, a train the first pinion of which (placed on the centre wheel arbor) revolves once in an hour, and the last wheel (which carries the moon on its axis) once in 29 days, 12 hours, 44 minutes, 3 seconds.

Pinions of 6, 9 and 37.
Wheels „ 91, 91 „ 171.

These numbers give the duration of a lunation within a fraction of a second. It is immaterial in what order the pinions gear with the wheels. Brocot's lunation train is given at page 111.

To Calculate a Lever Watch Train.

The fourth wheel turning 60 times for one turn of the centre wheel, the sum of the teeth in centre and third wheels multiplied together must be 60 times the product obtained by multiplying together the teeth of third and fourth pinions. *For Example,* to take the seconds train most in use for lever watches having third and fourth pinions of 8, we should have $8 \times 8 = 64$, and $64 \times 60 = 3840$. Any two numbers which when multiplied together make 3840 would be suitable for the centre and third wheels. But, unless some special numbers are desired, the calculation need not be carried further, because it is evident the two numbers we already have (64 and 60) will answer the condition. The escape wheel having 15 teeth turns once for every 30 vibrations of the balance, and with the train of 16,200, which is the most usual for lever watches we have $16{,}200 \div 30 = 540$ turns per hour for the escape pinion. As the fourth wheel turns 60 times an hour, the numbers for fourth wheel and escape pinion must be in the same ratio as 540 and 60, that is ($540 \div 60 = 9$) as 9 to 1. And if we decide on 7 for the scape pinion, we have $7 \times 9 = 63$ for the fourth wheel.

Note.—With a train of 14,400, the escape wheel turns 8 times; with 16,200, 9 times; and with 18,000, 10 times a minute.

Table of Lever Trains.

Centre Wheel.	Third Wheel.	Fourth Wheel.	Third Pinion.	Fourth Pinion.	Scape Pinion.	
64	60	64	8	8	8	Trains of 14400 4 vibrations per sec. Equidivisional seconds.
64	60	56	8	8	7	
60	56	56	8	7	7	
60	49	56	7	7	7	
64	60	48	8	8	6	
60	56	48	8	7	6	
60	49	48	7	7	6	
60	42	48	7	6	6	
56	45	48	7	6	6	
48	45	48	6	6	6	
60	48	48	8	6	6	
64	45	48	8	6	6	
64	60	72	8	8	8	Trains of 16200 $4\frac{1}{2}$ vibrations per sec. Imperfect seconds.
64	60	63	8	8	7	
64	56	63	8	7	7	
60	49	63	7	7	7	
64	60	54	8	8	6	
60	56	54	8	7	6	
60	49	54	7	7	6	
60	42	54	7	6	6	
56	45	54	7	6	6	
48	45	54	6	6	6	
60	48	54	8	6	6	
64	42	54	8	6	6	
80	75	72	10	10	8	

Centre Wheel	Third Wheel.	Fourth Wheel	Third Pinion.	Fourth Pinion	Scape Pinion.	
80	80	75	10	10	8	Trains of 18000 5 vibrations per sec. Equidivisional seconds.
64	60	80	8	8	8	
64	60	70	8	8	7	
64	56	70	8	7	7	
60	49	70	7	7	7	
*64	60	60	8	8	6	
60	56	60	8	7	6	
60	49	60	7	7	6	
60	42	60	7	6	6	
56	45	60	7	6	6	
48	45	60	6	6	6	
60	48	60	8	6	6	
64	45	60	8	6	6	

* This Train is also the one most generally used in Horizontal Watches.

Motion Work.

Below are given 12 sets of motion work. If any other numbers are desired the proportion is very easy to calculate.

The product obtained by multiplying together the minute and hour wheels must be 12 times that of the canon and minute wheel pinions. Applying this to the first set in the table, we have $12 \times 10 = 120$ and $40 \times 36 = 1440$, which is 12 times 120.

Trains for Motion Work.

Minute Wheel Pinions	12	14	16	12	14	16	18	14	16	18	16	18
Canon Pinions	10	10	10	12	12	12	12	14	14	14	16	16
Minute Wheels... ...	40	42	48	48	48	48	54	56	56	56	64	64
Hour Wheels	36	40	40	36	42	48	48	42	48	54	48	54

Of course, the number of wheels or pinions given in the table may be transposed. For instance, if canon is given as 12, and wheel pinion as 10, the canon may be 10, and the wheel pinion 12. But there is an advantage in making the canon the larger pinion, which is often overlooked. With a small canon pinion the oil is almost invariably drawn away from the centre wheel lower pivot. If a larger canon pinion is used a square sink or recess may be cut in it, which will effectually cure the evil referred to.

In house clocks the canon and minute wheel have each the same number of teeth for the convenience of letting off the striking work by means of the minute wheel, which thus turns in an hour; consequently the hour wheel and its pinion bear a proportion to each other of 12 to one. Generally a pinion of 6 and a wheel of 72 are used.

Fusees.

The calculation for Fusees is so simple as scarcely to call for any remark. The centre wheel turning once in an honr, and the turns on fusee being calculated for 30 hours, it is evident that the number of turns in any case is inversely proportionate to the number of times the teeth of centre pinion is contained in main wheel.

EXAMPLE—With main wheel of 75, and centre pinion of 10, $75 \div 10 = 7\frac{1}{2}$ and $30 \div 7\frac{1}{2} = 4$, which is the number of turns given in the table below.

FUSEES.

Main Wheel.	*Turns in Fusee to Centre Pinion of 10.*	*Turns in Fusee to Centre Pinion of 12.*	*Main Wheel.*	*Turns in Fusee to Centre Pinion of 10.*	*Turns in Fusee to Centre Pinion of 12*	*Main Wheel.*	*Turns in Fusee to Centre Pinion of 10.*	*Turns in Fusee to Centre Pinion of 12.*
40	$7\frac{1}{2}$	9	56	$5\frac{5}{14}$	$6\frac{3}{7}$	72	$4\frac{1}{6}$	5
42	$7\frac{1}{7}$	$8\frac{1}{7}$	58	$5\frac{5}{29}$	$6\frac{2}{37}$	74	$4\frac{2}{37}$	$4\frac{32}{37}$
44	$6\frac{9}{11}$	$8\frac{2}{11}$	60	5	6	75	4	$4\frac{4}{5}$
46	$6\frac{12}{13}$	$7\frac{19}{23}$	62	$4\frac{26}{31}$	$5\frac{25}{11}$	76	$3\frac{18}{19}$	$4\frac{14}{19}$
48	$6\frac{1}{4}$	$7\frac{1}{2}$	64	$4\frac{11}{19}$	$5\frac{5}{8}$	78	$3\frac{11}{13}$	$4\frac{8}{13}$
50	6	$7\frac{1}{5}$	66	$4\frac{6}{11}$	$5\frac{5}{11}$	80	$3\frac{3}{4}$	$4\frac{1}{2}$
52	$5\frac{10}{13}$	$6\frac{12}{13}$	68	$4\frac{7}{17}$	$5\frac{5}{17}$	84	$3\frac{7}{12}$	$4\frac{2}{7}$
54	$5\frac{5}{9}$	$6\frac{2}{3}$	70	$4\frac{2}{7}$	$5\frac{1}{7}$			

NOTE.—The proportion of the top to the bottom diameter of a Fusee can only be determined when the force of the spring at those two points is known; but in all cases the force at the top must bear the same proportion to the bottom diameter as the force at the bottom bears to the top diameter.

Marine Chronometer Trains.

	Great Wheel	*Centre Wheel.*	*Third Wheel.*	*Fourth Wheel.*	*Centre Pinion*	*Third Pinion*	*Fourth Pinion*	*Scape Pinion*	*Vibrations per Hour*	*Turns of Fusee.*
2 Day...	90	90	80	80	14	12	10	10	14400	8¾
8 Day...	144	90	80	80	12	12	10	10	14400	16

NOTE.—The two-day Marine Chronometer Train beating 14,400 is changed to an 18,000 train, and used for full-plate pocket chronometers, by substituting for the escape pinion of 10 an escape pinion of 8.

Independent Seconds Train.

For 18,000 movement in which the escape pinion has six leaves.

First Wheel	...	80	Pinion of	10
Second do.	...	64	,, ,,	8
Third do.	...	60	,, ,,	8
Fourth do.	...	60	,, ,,	8
Fifth do.	...	48	,, ,,	6

The train is arranged on the pillar plate. The first wheel is on the arbor of a small separate barrel. The fourth wheel pinion of the independent train is pierced to fit freely on the centre wheel arbor under the canon pinion, and carries the seconds hand. The last pinion of the independent train carries a flirt which takes into the leaves of the escape pinion of the usual train. The flirt, and therefore the last pinion of the independent train, thus makes six revolutions for each one of the escape pinion. It is essential that the centre wheel of the independent train should revolve once in a minute, and that the flirt should revolve once in a second. If therefore with an 18,000 train and escape wheel of fifteen teeth a higher numbered escape pinion than six is used, a separate pinion of six for the flirt to take into is fixed on the escape wheel arbor.

Conversions.

In converting a watch from a verge to a lever suitable numbers for the fourth wheel and escape pinion can be selected from the Table of Lever Trains on page 147 if the verge has a seconds train, that is, if the contrate wheel rotates once in a minute. For non-seconds train the following rule may be observed :—

Crown Wheel of 15.—When the verge has a crown wheel of 15 teeth and an escape pinion of either 7 or 8 use a pinion of the same number and a fourth wheel with the same number of teeth as the contrate wheel.

If the escape pinion of verge has 6 leaves use a pinion of 7 and add a sixth to the number of contrate wheel for fourth-wheel teeth. For instance, contrate wheel 54 and pinion of 6 ; use pinion of 7 and fourth wheel 63.

Crown Wheel of 13.—When the verge has an escape pinion of 6, use an escape pinion of 7 and the number of contrate wheel teeth for fourth wheel. (The effect will be to take a ninetieth part from the original number of vibrations, which in a train not exceeding 18,000 will never exceed 198).

When the verge has an escape pinion of 7, use an escape pinion of 8 and the number of contrate wheel teeth for fourth wheel. (This will add a one-hundredth part to the original number of vibrations).

Crown Wheel of 11.—When the verge has an escape pinion of 6, use an escape pinion of 8 and one less than the number of contrate wheel teeth for fourth wheel.

When the verge has an escape pinion of 7, use a pinion of 8 and a fourth wheel with one-sixth less teeth than the contrate wheel.

Crown Wheel of 9.—The few verge trains with crown wheel of nine have escape pinions of 6. In converting use an escape pinion of 8 and a fourth wheel with one-fifth less teeth than the contrate wheel.

Full directions for applying the balance-spring are given at page 63, but before selecting the spring it is necessary to ascertain the number of vibrations.

Multiply together 30 and the numbers of centre, third and fourth wheels.

Also multiply together the numbers of third, fourth and escape pinions.

Divide the first product by the second, and the result will be the number of vibrations per hour.

For example: take a watch with centre wheel 80, third 72, fourth 50, and pinions of 8. Here $30 \times 80 \times 72 \times 50 = 8640000$, and $8 \times 8 \times 8 = 512$. Then $8640000 \div 512 = 16{,}875$, the number of vibrations per hour. The number of vibrations per minute can, of course, be obtained by dividing this number by 60.

It is also useful in bringing the watch to time to know the number of seconds in which the fourth wheel revolves.

Multiply together 3,600 and the numbers of third and fourth pinions.

Also multiply together the numbers of centre and third wheels.

Divide the first product by the second, and the result will be the time of one revolution of fourth wheel in seconds.

Taking the preceding example:—$3{,}600 \times 8 \times 8 = 230400$, and $80 \times 72 = 5{,}760$. Then $230400 \div 5{,}760 = 40$ secs.

The above rules render the calculation of conversions so simple that Tables of Trains appear unnecessary; but for the few who still desire them they are appended.

TABLE GIVING CHOICE OF TWO CONVERSIONS WHERE THE SCAPE WHEEL OF VERTICAL HAS 9 AND THE SCAPE WHEEL OF LEVER IS TO HAVE 15 TEETH. THE THICK FIGURES IN EACH GROUP REFER TO THE VERTICAL.

*(Trains marked thus * give a fraction more than the number of vibrations stated.)*

Centre wheel.	Third wheel.	Fourth wheel.	Third pinion.	Fourth pinion.	Scape pinion.	Vibrations per hour.	No of secs. for 1 revolution of fourth wheel.	Centre wheel.	Third wheel.	Fourth wheel.	Third pinion.	Fourth pinion.	Scape pinion.	Vibrations per hour.	No. of secs. for 1 revolution of fourth wheel.
60	**58**	**52**	**6**	**6**	**6**	**15080**		**62**	**60**	**54**	**6**	**6**	**6**	**16740**	
...	...	36	...	...	7	14914*	37.24	...	...	37	...	...	7	16385*	34.83
...	...	41	...	..	8	14862*		...	...	43	...	...	8	16662*	
60	**58**	**56**	**6**	**6**	**6**	**16240**		**64**	**60**	**54**	**6**	**6**	**6**	**17280**	
...	...	39	...	...	7	16157*	37.24	...	...	37	...	...	7	16914*	33.75
...	...	44	...	...	8	15950		...	...	43	...	...	8	17200	
60	**60**	**54**	**6**	**6**	**6**	**16200**		**70**	**60**	**56**	**7**	**7**	**6**	**14400**	
...	..	37	...	...	7	15857*	36.	...	...	39	...	...	7	14326*	42.
...	...	43	..	...	8	16125		...	...	44	...	...	8	14142*	
60	**60**	**60**	**6**	**6**	**6**	**18000**		**70**	**60**	**60**	**7**	**7**	**6**	**15428***	
...	...	42	...	...	7	...	36.	...	...	42	...	...	7	...	42.
...	...	48	...	...	8	...		...	...	48	...	...	8	...	

Table with Choice of Two Conversions where the Scape Wheel of Vertical has 11 Teeth and the Scape Wheel of Lever is to have 15 Teeth. The Thick Figures in each Group refer to the Vertical.

(Trains marked thus give a fraction more than the number of vibrations stated.)*

Centre wheel.	Third wheel.	Fourth wheel.	Third pinion.	Fourth pinion.	Scape pinion.	Vibrations per hour.	No of secs for 1 revolution of fourth wheel	Centre wheel.	Third wheel.	Fourth wheel.	Third pinion.	Fourth pinion.	Scape pinion.	Vibrations per hour.	No of secs for 1 revolution of fourth wheel.
54	**50**	**60**	6	6	6	16500		**60**	**54**	**50**	6	6	6	16500	
...	...	44	...	...	...	...	,, 48.	...	...	36	...	...	...	16200	,, 40.
...	...	51	...	...	7	16322*		...	...	42	...	...	7	—	
56	**54**	**54**	6	6	6	16632		**60**	**54**	**52**	6	6	6	17160	
..	...	39	...	...	...	16380	42.85	...	...	38	...	...	...	17100	40.
...	...	46	...	...	7	16560		...	...	44	...	...	7	16971*	
56	**56**	**55**	6	6	6	17567*		**60**	**55**	**52**	6	6	6	17477*	
...	...	40	...	...	...	17422*	41.32	...	...	38	...	...	...	17416*	39.27
...	...	47	...	...	7	17546*		...	...	44	...	...	7	17285*	
58	**52**	**52**	6	6	6	15973*		**60**	**54**	**54**	6	6	6	17820	
...	...	38	...	...	...	15917*	42.97	...	...	39	...	...	...	17550	40.
...	...	44	...	...	7	15798*		...	...	46	...	...	7	17742*	
58	**54**	**54**	6	6	6	17226		**60**	**56**	**50**	6	6	6	17111*	
...	...	39	...	...	...	16965	41.37	...	...	36	...	...	...	16800	38.85
...	...	46	...	...	7	17151*		...	...	42	...	...	7	—	
58	**54**	**52**	6	6	6	16588		**58**	**56**	**56**	7	0	6	15879*	
...	...	38	...	...	..	16530	41.37	...	...	41	...	...	...	15853*	46.55
...	...	44	...	...	7	16405*		...	...	47	...	...	7	15577*	
58	**56**	**54**	6	6	6	17864		**60**	**56**	**56**	7	6	6	16426*	
...	...	39	...	...	...	17593*	39.90	...	...	41	...	...	...	16400	45.
...	...	46	...	...	7	17786*		...	..	47	...	...	7	16114*	
60	**50**	**52**	6	6	6	15888*		**60**	**60**	**48**	6	6	6	17600	
...	...	38	...	...	...	15833*	43.20	...	...	35	...	...	...	17500	36.
...	...	44	...	...	7	15714*		...	...	41	...	...	7	17571*	
60	**52**	**52**	6	6	6	16524*		**62**	**54**	**52**	6	6	6	17732	
...	...	38	...	...	...	16466*	,, 41.53	...	..	38	...	...	...	17670	38.70
...	...	44	...	...	7	16342*		...	...	44	...	...	7	17537*	

Centre wheel.	Third wheel.	Fourth wheel.	Third pinion.	Fourth pinion.	Scape pinion.	Vibrations per hour.	No. of seconds for 1 revolution of fourth wheel.
63	54	50	6	6	6	17325	38"·09
...	...	36	...	...	...	17010	
...	...	42	...	...	7	—	
64	50	50	6	6	6	16296	40·08
...	...	36	...	...	...	16000	
...	...	42	...	...	7	—	
64	52	52	6	6	6	17626*	38·84
...	...	38	...	...	...	17564*	
...	...	44	...	...	7	17432*	
63	56	56	7	6	6	17248	42·85
...	...	41	...	...	...	17220	
...	...	47	...	...	7	16920	
62	58	52	7	6	6	16324*	42·04
...	...	38	..	...	...	16267*	
...	...	44	...	...	7	16145*	
60	60	60	7	7	6	16163*	49·
...	...	44	...	...	...	—	
...	...	51	...	...	7	16058*	
63	63	58	7	7	6	17226	44·44
...	...	42	...	...	...	17010	
...	...	49	...	...	7	—	
65	62	59	7	7	7	15250*	43·77
...	...	43	...	...	...	15156*	
...	...	49	...	...	8	15112*	
68	63	63	7	7	7	17310*	41·42
...	...	45	...	...	...	16861*	
...	...	52	...	...	8	17048*	
70	63	58	7	7	7	16405*	40·
...	...	42	..	...	...	16200	
...	...	48	..	...	8	—	
70	63	60	7	7	7	16971*	40·
...	...	44	...	..	...	—	
...	...	50	...	...	8	16875	

Centre wheel.	Third wheel.	Fourth wheel.	Third pinion.	Fourth pinion.	Scape pinion.	Vibrations per hour.	No. of seconds for 1 revolution of fourth wheel.
70	64	60	7	7	7	17240*	39"·37
...	...	44	...	...	...	—	
...	...	50	...	...	8	17142*	
72	63	60	7	7	7	17456*	38·88
...	...	44	...	...	...	—	
...	...	50	...	...	8	17357*	
72	64	58	7	7	7	17142*	38·28
...	...	42	...	...	...	16927*	
...	...	48	...	...	8	—	
60	60	56	8	6	6	15400	48·
...	...	41	...	...	...	15375	
...	...	47	...	...	7	15107*	
64	58	58	8	6	6	16446*	46·55
...	...	42	...	...	...	16240	
...	...	49	...	...	7	—	
64	56	56	8	6	6	15331*	48·21
...	...	41	...	...	...	15306*	
...	...	47	...	...	7	15040	
70	54	68	8	7	6	16830	58·33
...	...	49	...	...	...	16537*	
...	...	58	...	...	7	16778*	
72	63	54	8	7	6	16038	44·44
...	...	39	...	...	...	15795	
...	...	46	...	...	7	15968*	
72	64	54	8	7	6	16292*	43·75
...	...	39	...	...	...	16045*	
...	...	46	...	...	7	16222*	
75	68	68	8	8	7	17030*	45·16
...	...	49	...	...	...	16734*	
...	...	56	...	...	8	—	
80	72	68	8	8	8	16830	40·
...	...	49	...	...	...	16537*	
...	...	50	...	...	...	16875	

Table giving One Conversion where the Scape Wheel of Vertical has 13 Teeth, and the Scape Wheel of Lever is to have 15 Teeth. The Thick Figures refer to the Vertical.

[It will be seen that the number of scape pinion teeth is the same after as before conversion, but as a higher numbered pinion may be desired, it is well to know that any vertical train having 13 in scape wheel and a scape pinion of 6 may be converted into a suitable lever train by substituting a scape wheel of 15 and a scape pinion of 7. The effect will be to diminish the original train by one 91th part of its whole number, which in any train not exceeding 18000 will never amount to more than 198. Also, any train having 13 in scape wheel and scape pinion 7, would, by substituting a scape wheel of 15 and scape pinion of 8, have the original train increased by one 104th of its whole number, which in trains not exceeding 18000 could never exceed 173.]

Centre Wheel.	*Third Wheel.*	*Fourth Wheel.*	*Third Pinion.*	*Fourth Pinion.*	*Scape Pinion.*	*Vibrations per hour.*	*No. of seconds for one revolution of fourth wheel.*	*Centre Wheel.*	*Third Wheel.*	*Fourth Wheel.*	*Third Pinion.*	*Fourth Pinion.*	*Scape Pinion.*	*Vibrations per hour.*	*No. of seconds for one revolution of fourth wheel.*
52	**52**	**52**	6	6	6	16925*	,,	**56**	**52**	**50**	6	6	6	17525*	,,
...	...	45	...	...	..	16900	47·92	...	...	43	...	...	...	17391*	44·50
54	**50**	**50**	6	6	6	16250	48·	**56**	**54**	**48**	6	6	6	17472	42·85
...	...	43	...	...	...	16125		...	...	41	...	...	...	17220	
54	**52**	**48**	6	6	6	16224	46·15	**58**	**48**	**52**	6	6	6	17425*	46·55
...	...	41	...	...	...	15990		...	...	45	...	...	...	17400	
54	**52**	**50**	6	6	6	16900	46·15	**58**	**48**	**50**	6	6	6	16755*	46·55
...	...	43	...	..	...	16770		...	...	43	...	...	...	16626*	
54	**52**	**51**	6	6	6	17238	46·15	**58**	**50**	**50**	6	6	6	17453*	44·69
...	...	44	...	...	...	17160		...	...	43	...	...	...	17319*	
54	**52**	**52**	6	6	6	17576	46·15	**60**	**48**	**48**	6	6	6	16640	45·
...	...	45	...	...	...	17550		...	...	41	...	...	...	16400	
54	**53**	**50**	6	6	6	17225	45·28	**60**	**50**	**48**	6	6	6	17333*	43·20
...	...	43	...	...	...	17092*		...	.	41	...	...	..	17083*	
55	**51**	**51**	6	6	6	17219*	46·20	**60**	**50**	**46**	6	6	6	16611*	43·20
...	...	44	...	...	...	17141*		...	...	39	...	...	...	16250	
56	**50**	**50**	6	6	6	16851*	46·28	**60**	**54**	**52**	7	6	6	17382*	46·66
...	...	43	...	...	...	16722*		...	...	45	...	...	...	17357*	

Centre Wheel.	*Third Wheel.*	*Fourth Wheel.*	*Third Pinion.*	*Fourth Pinion.*	*Scape Pinion.*	*Vibrations per hour.*	*No. of seconds for one revolution of fourth wheel.*	*Centre Wheel.*	*Third Wheel.*	*Fourth Wheel.*	*Third Pinion.*	*Fourth Pinion.*	*Scape Pinion.*	*Vibrations per hour.*	*No. of seconds for one revolution of fourth wheel.*
56	**50**	**51**	**6**	**6**	**6**	**17188***	″ 46·28	**60**	**60**	**48**	**7**	**6**	**6**	**17828***	″ 42·
...	...	44	...	...	...	17111*		...	...	41	...	...		17571*	
56	**52**	**48**	**6**	**6**	**6**	**16824***	44·50	**63**	**52**	**51**	**7**	**6**	**6**	**17238**	46·15
...	...	41	...	..	...	16582*		..	...	54	...	...	..	17160	
64	**52**	**50**	**7**	**6**	**6**	**17168***	45·43	**60**	**54**	**60**	**8**	**6**	**6**	**17550**	53·33
...	...	43	...	...	...	17036*		...	...	52	...	...	...	—	
60	**56**	**56**	**7**	**7**	**6**	**16640***	52·50	**60**	**58**	**56**	**8**	**6**	**6**	**17593***	49·65
...	...	48	...	...	...	16457*		...	...	48	...	...	...	17400	
60	**58**	**56**	**7**	**7**	**6**	**17234***	50·69	**60**	**60**	**54**	**8**	**6**	**6**	**17550**	48·
...	...	48	...	...	...	17044*		...	...	46	...	...	...	17250	
60	**60**	**56**	**7**	**7**	**6**	**17828***	49·	**64**	**58**	**50**	**8**	**6**	**6**	**16755***	46·55
...	...	48	...	...	...	17632*		...	...	43	...	...	...	16626*	
62	**56**	**56**	**7**	**7**	**6**	**17194***	50.80	**72**	**52**	**51**	**8**	**6**	**6**	**17238**	46·15
...	...	48	...	...	...	17005*		...	...	44	...	...	...	17160	
63	**60**	**52**	**7**	**7**	**6**	**17382***	46·66	**70**	**60**	**52**	**8**	**7**	**6**	**16900**	48·
...	...	45	...	...	...	17357*		...	...	45	...	...	...	16875	
64	**60**	**50**	**7**	**7**	**6**	**16979***	45·93	**70**	**60**	**50**	**8**	**7**	**6**	**16250**	48.
...	...	43	...	..	...	16848*		...	...	43	...	...	...	16125	
63	**60**	**60**	**7**	**7**	**7**	**17191***	46·66	**70**	**60**	**54**	**8**	**7**	**6**	**17550**	48.
...	...	52	...	...	...	—		...	...	46	...	...	...	17250	
64	**60**	**60**	**7**	**7**	**7**	**17464***	45·93	**72**	**64**	**56**	**8**	**7**	**7**	**17115***	43.75
...	...	52	...	...	...	—		...	...	48	...	...	...	16927*	
65	**62**	**58**	**7**	**7**	**7**	**17717***	43·77	**64**	**64**	**72**	**8**	**8**	**7**	**17115***	56·25
...	...	50	...	...	...	17623*		...	...	62	...	...	...	17005*	
68	**60**	**56**	**7**	**7**	**7**	**17319***	43·23	**70**	**66**	**64**	**8**	**8**	**7**	**17160**	49·87
...	...	48	...	...	...	17128*		...	...	55	...	...	...	17015*	
70	**60**	**56**	**7**	**7**	**7**	**17828***	42·	**72**	**64**	**64**	**8**	**8**	**7**	**17115***	50·
...	...	48	...	...	...	17632*		...	...	55	...	...	...	16971*	
72	**56**	**56**	**7**	**7**	**7**	**17115***	43·75	**72**	**66**	**63**	**8**	**8**	**7**	**17374***	48·48
...	...	48	...	...	...	16927*		...	...	54	...	...	...	17183*	

* **These trains give a fraction more than the number of vibrations stated.**

Date Marks on Gold and Silver Plate and Watc

NOTE.—The Date Mark is altered

a	1697	A	1716-7	a	1736-7	A	1756-7	a	1776-7	[illegible]	177[illegible]
b	1697-8	B	1717-8	b	1737-8	B	1757-8	b	1777-8	[illegible]	177[illegible]
c	1698-9	C	1718-9	c	1738-9	C	1758-9	c	1778-9	[illegible]	17[illegible]
d	1699-0	D	1719-0	d	1739-0	D	1759-0	d	1779-0	[illegible]	177[illegible]
e	1700-1	E	1720-1	e	1740-1	E	1760-1	e	1780-1	[illegible]	1780[illegible]
f	1701-2	F	1721-2	f	1741-2	F	1761-2	f	1781-2	[illegible]	1781[illegible]
g	1702-3	G	1722-3	g	1742-3	G	1762-3	g	1782-3	[illegible]	178[illegible]
h	1703-4	H	1723-4	h	1743-4	H	1763-4	h	1783-4	[illegible]	178[illegible]
i	1704-5	I	1724-5	i	1744-5	I	1764-5	i	1784-5	[illegible]	1784[illegible]
k	1705-6	K	1725-6	k	1745-6	K	1765-6	k	1785-6	[illegible]	178[illegible]
l	1706-7	L	1726-7	l	1746-7	L	1766-7	l	1786-7	[illegible]	178[illegible]
m	1707-8	M	1727-8	m	1747-8	M	1767-8	m	1787-8	[illegible]	178[illegible]
n	1708-9	N	1728-9	n	1748-9	N	1768-9	n	1788-9	[illegible]	178[illegible]
o	1709-0	O	1729-0	o	1749-0	O	1769-0	o	1789-0	[illegible]	178[illegible]
p	1710-1	P	1730-1	p	1750-1	P	1070-1	p	1790-1	[illegible]	1790-1
q	1711-2	Q	1731-2	q	1751-2	Q	1771-2	q	1791-2	[illegible]	1791-2
r	1712-3	R	1732-3	r	1752-3	R	1772-3	r	1792-3	[illegible]	1792-3
s	1713-4	S	1733-4	ſ	1753-4	S	1773-4	s	1793-4	[illegible]	1793-4
t	1714-5	T	1734-5	t	1754-5	T	1774-5	t	1794-5	[illegible]	1794-5
u	1715-6	V	1735-6	u	1755-6	U	1775-6	u	1795-6	[illegible]	1795-6

THE STANDARD MARK for Sterling Silver is a lion passant. A lion passant was also the standard mark on 22 carat gold up to 1845. For Gold of 22 carats the standard mark is now a crown and the figures 22. For 18 carat Gold the standard mark is a crown and the figures 18.

For 15 carat Gold	15 and ·625	}	Pure Gold being 24 carats these decimals
,, 12 ,,	12 ,, ·5	}	represent the proportion of pure Gold
,, 9 ,,	9 ,, ·375	}	in the article so marked.

THE LONDON HALL MARK is a Leopard's Head, which prior to 1823 was crowned.

es marked at Goldsmith's Hall, London.

the 30th of May in each year.

[illegible]	1796-7	a	1816-7	A	1836-7	a	1856-7	A	1876-7
[illegible]	1797-8	b	1817-8	B	1837-8	b	1857-8	B	1877-8
[illegible]	1798-9	c	1818-9	C	1838-9	c	1858-9	C	1878-9
[illegible]	1799-0	d	1819-0	D	1839-0	d	1859-0	D	1879-0
[illegible]	1800-1	e	1820-1	E	1840-1	e	1860-1	E	1880-1
[illegible]	1801-2	f	1821-2	F	1841-2	f	1861-2	F	1881-2
[illegible]	1802-3	g	1822-3	G	1842-3	g	1862-3	G	1882-3
[illegible]	1803-4	h	1823-4	H	1843-4	h	1863-4		
[illegible]	1804-5	i	1824-5	I	1844-5	i	1864-5		
[illegible]	1805-6	k	1825-6	K	1845-6	k	1865-6		
[illegible]	1806-7	l	1826-7	L	1846-7	l	1866-7		
[illegible]	1807-8	m	1827-8	M	1847-8	m	1867-8		
[illegible]	1808-9	n	1828-9	N	1848-9	n	1868-9		
[illegible]	1809-0	o	1829-0	O	1849-0	o	1869-0		
[illegible]	1810-1	p	1830-1	P	1850-1	p	1870-1		
[illegible]	1811-2	q	1831-2	Q	1851-2	q	1871-2		
[illegible]	1812-3	r	1832-3	R	1852-3	r	1872-3		
[illegible]	1813-4	s	1833-4	S	1853-4	s	1873-4		
[illegible]	1814-5	t	1834-5	T	1854-5	t	1874-5		
[illegible]	1815-6	u	1835-6	U	1855-6	u	1875-6		

And so on till the cycle of twenty years is completed.

Head of the Reigning Sovereign denotes that duty has been paid. Watch cases were ex- l from duty in 1798.

Maker's Mark before 1697 was some emblem selected by him; in that year it was ordered to two first letters of his surname; since 1739 it has been the initials of the maker's Christian rnames.

397 the quality of standard Silver was raised from 11oz. 2dwts. to 11ozs. 10dwts of pure .n 12ozs. of plate, and a lion's head used as the standard mark and a figure of Britannia as the ırk, but in 1823 the old standard of 11ozs. 2dwts. and the old marks of a lion passant and a l's head were reverted to.

Hall Marks of Other Assay Offices.

CHESTER.—A sword between three wheatsheaves. Prior to 1779 it was three demi lions and a wheatsheaf on a shield.

BIRMINGHAM.—An anchor.

SHEFFIELD.—A crown (silver only is assayed).

EXETER.—A castle with three towers.

YORK.—Five lions on a cross.

NEWCASTLE.—Three castles.

NORWICH.—A castle and lion passant. (The Norwich Assay Office is now closed.

EDINBURGH has a thistle for the standard mark and a castle for the hall mark.

GLASGOW has a lion rampant for the standard and a tree, a fish and bell for the hall mark.

DUBLIN has a harp crowned as the standard mark for sterling silver and for 22 carat gold with the figures 22 added in the latter case ; for 20 carat gold a plume of three feathers and 20 ; for 18 carat gold a unicorn head and 18. The lower qualities of 15, 12 and 9 are marked with the same standard mark as is used at the London Hall. The Hall Mark for Dublin is a figure of Hibernia.

Value of Gold.

		£	s.	d.			£	s.	d.
Value of Gold per Ounce Troy	Pure gold...	£4	5	0	Value of Gold per Ounce Troy	13 Carat ...	£2	6	0¼
	22 Carat ..	3	17	11		12 Carat ...	2	2	6
	18 Carat ...	3	3	9		9 Carat ...	1	11	10½
	15 Carat ...	2	13	1½		8 Carat ...	1	8	4

The above is the Mint value of the gold. The value of the alloy is not taken into account, but in dealing with any considerable quantity of gold alloyed with silver the value of the latter may be worth consideration. As a rule one third to one half of the alloy in gold chains and jewellery is silver.

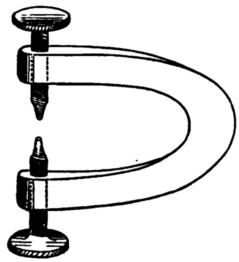
Useful Memoranda.

Timing French Pendules.—Escape wheels of French pendules make two revolutions a minute, or four vibrations to each tooth. They may be quickly brought to time by counting if the beats of pendulum per minute equals four times the number of teeth in scape wheel.

Timing Repeating Carriage Clocks.—The quickest method is to listen to the first blow of the hammer on the bell (or gong) at each hour and half-hour, noting at the same time the position of the seconds hand on the regulator. Thus: supposing the blow is given exactly at 12·0′0″, make a note of it, and compare again at 12·30′0″, when probably the half-hour blow will be given at 12·30′5″; make a note of this also, but do not alter the index, as this difference arises from the imperfect position of the half-hour pin in canon wheel; at 1·0′0″ compare as before, and as it is the same pin coming into action as at 12·0′0″, any difference in the time of the first blow will be indicative of a gain or loss, as the case may be; thus: it may be given at 1·0′4″, which will show a loss of 4″ in the last hour, and the clock may be now regulated accordingly. The blow may next be given at 1.30′8″, showing the effect the moving of the index has had in making it gain 1″ in the preceeding half-hour; regulate and compare again at 2·0′0″, and if the first blow is given at 2·0′3″ it will show that the clock has been keeping correct time for the last half-hour.

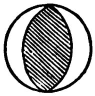
To Widen a Jewel Hole.—Chuck the hole in the lathe with cement. Place a spirit-lamp underneath to prevent the cement hardening. Hold a pointed bit against the hole while the lathe is running until the hole is true, when remove the lamp. The broach to widen the hole should be made of copper, of the size and shape required, and the point after being oiled should be rolled in diamond-dust until it is entirely covered. The diamond-dust should then be beaten in with a burnisher, using very light blows so as not to bruise the broach. After the hole is widened as desired, it requires polishing with a broach made of ivory and used with oil and the finest diamond dust, loose (not driven into the broach). Watch jewellers polish the holes with a copper broach, using *very fine* diamond powder and a high rate of speed.

To Extract Broken Watch Screws.—Make a cramp like the drawing, large enough to reach across a watch plate, very strong just at the bow, so as to stand any screwing up without springing. Provide two or three sets of steel screws with different-sized *hardened* points. To use it, tighten that screw of the cramp which is against the *point* of the broken screw; and when you have a firm grip, turn the whole tool round, and the broken screw will invariably be drawn out.



Another Method.—The cramp would be of no avail if the screw hole is drilled only partly through the plate. In such a case slightly warm the plate and well cover it with beeswax. Be careful not to let the wax touch the broken screw; then make a solution of oil of vitriol—1 part of oil of vitriol and 4 of water. Let it stand until quite cold, then put the plate in, and in a few hours the acid will dissolve the screw. The wax may be removed by warming it in olive oil, and washing in hot soap and water.

To make a Left-Handed Screw Plate.—Screw a piece of steel of the desired size, in an ordinary right-handed screw plate. Then file it away to a feather-edge, something the shape of the shaded part in the sketch annexed, and harden it. A good left-handed screw plate may now be cut with the tap thus made if it is turned the reverse, or left-handed way.



To Drill or Broach Holes in Enamel Dials.—Use a flat ended drill or a conical broach of copper into which diamond powder has been hammered.

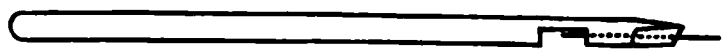
Repairing Fusee Top Pivot.—First file up and re-polish the square, taking off the corners sufficiently to prevent them standing above the pivot when it is re-polished. Put the square into a concentric arbor and get the fusee quite true. Now put a screw ferrule on to the fusee back arbor, and place the whole piece in the turns with the concentric in front, using the bow on the ferrule at back. If the pivot is much cut it should be turned slightly with the point of the graver. Polish first with steel and coarse stuff, afterwards with bell metal and fine stuff, and finish with the glossing burnisher.—H.B.

To "put in" Fusee Top Hole.—Put the pillar plate in the mandre and peg the bottom hole true, then turn out the top hole to the required size for stopping. The stopping (a hollow one) should be small, and no longer than just sufficient to form the rivet. If there be danger of bending the plate the stopping should be softened slightly (the hammering will re-harden it), and the ends turned hollow to facilitate the rivetting. The top hole is now to be turned to nearly right size for the pivot, testing it frequently for truth with the peg, as much broaching is especially to be avoided. In finishing the stopping use POLISHED cutters, take off the corners of the hole, and polish the cup or chamfer for the oil with peg and redstuff. The same procedure is to be followed with ¾ plate fusee, and it will be found best to finish the stopping in fusee piece before screwing the steel on to the brass. Be careful to give the fusee but little end shake; if it be at all excessive the stop work and the maintaining work will become uncertain, and either or both may fail.—H.B.

To put in Centre Bottom Hole.—First re-polish the pivot, taking care to burnish it well. Put the frame in the mandrel holding by the top plate, and centre from the top hole. Peg the bottom hole quite true, and turn it to take a small stopping. Turn a stopping to fit the hole tight, and take care not to have it longer than enough to rivet properly. Care will be required in rivetting to avoid hammer marks and bending the plate. It may be done best with a steel punch slightly hollow on the face, and with a pivot in the centre to enter the hole of stopping. Re-place pillar plate in mandrel (the top plate having remained there meanwhile) and turn out the hole quite true, testing it by the peg, and to nearly right size for the pivot. Broach it in carefully, finishing with a clean and well-polished round broach, and turn off and finish stopping with POLISHED cutters. Fit the stopping from the inside of plate, tap it slightly to drive it in, resting the plate on a piece of pegwood held in the vice and having a hole drilled up it of a size to fit the stopping.—H.B.

Crossing-out Wheels.—The radius of a circle divides the circumference into six equal parts, and the marks so placed would denote the position of the arms for wheels with six arms. For wheels with three arms every other mark may be taken.

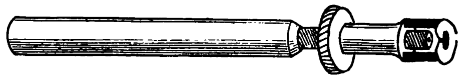
To fit Bouchons.—After repairing the pivot a bouchon must be selected as small as the pivot will admit, for the smaller the bouchon is the neater will be the job. Open the hole of the plate or cock so that the bouchon which should be previously lightly draw-filed at the end, will stand with a slight pressure upright in the opened hole of the plate or cock. Then with a knife cut it across at the part where it is to be broken off, so that it may break very readily when required to do so. Press it in the plate on the side the pivot works, break off, and then drive it home with a small centre punch. In every repair of this nature notice should be taken of the amount of end shake of the pinion, and allowance made by leaving the bouchon so that any excess may be corrected. To finish off the shoulder end a small chamfering tool like the sketch should be used.



It has a hole smaller than the pivot one, to receive a fine brass wire serving as a centre to prevent the tool changing its position while being used; or the wire may be put through the bouchon hole, and then the hole of the tcol may be left open. The above is a far more expeditious way than using the mandrel.

Watch Hands.—The best way of taking off watch and chronometer hands is to insert the points of two small gun-metal levers (like miniature crowbars) under the hour hand socket, one on either side; a piece of thin paper may be interposed between the dial and the hands When the hands are removed in this way there is no fear of cracking the dial or deforming the hands. The points of the levers will occasionally require to be dressed up. For marine chronometer hands boxwood levers are often used, In some cases there is not room to insert the levers, and then a good plan is to provide a pair of sound pliers without any shake at the joint, with points shaped as in the sketch annexed, and nicely hardened and polished. They can be inserted between a very close minute and hour hand. They retain the hand; do not injure it like the nippers do, and are more under control than tweezers shaped in the same way.

A very useful tool for holding watch hands while broaching the hole is here shown. It consists of a lantern very similar to those used in the Geneva Screw Head Tool, with an extra long boss for the screw, and with the face of the lantern cut away, as shown, to suit the hand. There is a knurled lock-nut to ensure the hand being held fast when it is once jammed up, and a hole is pierced right through the handle of the tool to permit of the passage of the broach. A pair of sliding-tongs, with wide jaws, one having a series of holes in it to let the bosses of different-sized hands pass through, also forms a good tool for the purpose.



In opening the hole of a watch hand to size time will be saved if, supposing the boss of the old hand is available, a broach be tried in the hole of the old hand, and the distance it will enter marked on it by pushing a slip of cork on the broach in front of the old boss. The new hand may then be broached out to the cork with confidence before trying it on.

If it is desired to close the hole of a minute hand the corner of the boss may be turned off at an angle, leaving the metal thin round the hole, and the hand then placed on a stake and one smart blow given to the boss with a flat-surfaced hammer. An hour hand too large may have a slit cut through the boss, which is then sprung together. Some use a stake with a series of conical holes for placing the boss of the hand in. The hole is then closed by striking the hand; but even with this stake if the boss is very stout the corner must be turned off. It is better to broach a seconds hand out full large and then give it a nip to make it grasp the pivot, for if it is a thoroughly good fit throughout the length of the boss there is danger of breaking the pivot in removing it.

To Bleach Watch-Dials, &c.—Dissolve ½oz. cyanide of potassium in a quart of hot water, and add 2oz. strong liquor ammonia and ⅛oz. spirits of wine (these two may have been mixed previously). Dip the dials, whether silver, gold or gilt, in it for a few seconds, then put them in warm water; brush well with soap, and afterwards brush; rinse and dry in hot box-wood dust. Another good plan is to gently heat the dial and dip in diluted nitric acid, but this must not be adopted for dials with painted figures, for the figures would be destroyed.

Broaching Horizontal Escape Wheels.—A holder like the one described above for watch hands is also very useful fer gripping horizontal escape wheels while they are being broached. The face of the lantern, however, is of a different form. There are four pillars instead of two, and there is a projection at the end of each pillar, very much like the tooth of a horizontal escape wheel, so as to form what is called a bayonet point. Here is a sketch of the end of the lantern. The arms of the wheel enter the criciform slits; the wheel is turned as far as the pillars will allow, and then when the screw is tightened the wheel is gripped between the screw and the projections. Before the hole is broached a bit of wire should be inserted in the hole and a flame directed on the other end of the wire. Sufficient heat will pass along the wire to lower the temper of the hole.

Silvering Watch and Clock Dials.—Dissolve a stick of nitrate of silver in half a pint of rain water; add two or three table-spoonfuls of common salt, which will at once precipitate the silver in the form of a thick white curd, called chloride of silver. Let the chloride settle until the liquid is clear; pour off the water, taking care not to lose any chloride; add more water, thoroughly stir and again pour off, repeating till no trace of salt or acid can be perceived by the taste. After draining off the water, add to the chloride about two heaped table-spoonfuls each of salt and cream of tartar and mix thoroughly into a paste, which, when not in use, must not be exposed to the light. To silver a surface of engraved brass, wash the surface clean with a stiff brush and soap. Heat hot enough to melt black sealing-wax, which rub on with a stick of wax until the engraving is entirely filled, care being taken not to burn the wax. With a piece of flat pumice-stone, and some pulverised pumice-stone and plenty of water, grind off the wax until the brass is exposed in every part; the stoning being constantly in one direction. Finish by laying an even and straight grain across the brass with blue or water of Ayr stone. Take a small quantity of pulverized pumice-stone on the hand and slightly rub in the same direction, which tends to make an even grain; the hands must be entirely free from soap or grease. Rinse off the brass thoroughly, and before it dries lay it on a clean board and gently rub the surface with fine salt, using a small wad of clean muslin. When the surface is thoroughly charged and covered with salt, put upon the wad of cloth, done up with a smooth surface, a sufficient quantity of the paste, say to a dial three inches in diameter, a piece of the size of a marble, which rub evenly and quickly over the entire surface. The brass will assume a greyish, streaked appearance; add quickly to the cloth cream of tartar moistened with water into a thin paste; continue rubbing until all is evenly whitened. Rinse quickly under a copious stream of water; and in order to dry it rapidly, dip into water as hot as can be borne by the hands, and when heated, holding the brass by the edges, shake off as much of the water as possible, and remove any remaining drops with a clean dry cloth. The brass should then be heated gently over an alcohol lamp, until the wax glistens without melting, when it may be covered with a thin coat of spirit varnish. laid on with a broad camel's-hair brush. The varnish or lacquer must be quite light-coloured—diluted to a pale straw colour.

Velocity of Sound.—In noting the time of the striking of a clock on the firing of a gun at a distance a correction should be made for the velocity of sound which at a temperature of 50° Far. is 1,110 feet a second. The direction of the wind through it may intensify or deaden the sound, would not affect its velocity,

Polishing Marble Clock Cases.—Make a thin paste of best beeswax and spirits of turpentine, clean the case well from dust, &c., then slightly cover it with the paste, and with a handful of clean cotton wool rub it well, using abundant friction; finish off with a clean old linen rag, which will produce a brilliant black polish. For light-coloured marble cases mix quick-lime with strong soda water, and cover the marble with a thick coating. Clean off after 24 hours and polish well with fine putty powder.

To Divest Steel Work of Magnetism.—It is necessary to have three or four magnets of different sizes, also a good horse-shoe magnet for re-charging, for these straight magnets soon lose strength. A piece of bar-steel of the required size, hardened first, and then charged by the horse-shoe magnet, answers the purpose, or an old worn-out round or square file, or stump of an old graver, will do equally well, and save the trouble of hardening. The size of the magnet used must be determined by the size of the article operated on. Take a watch balance for instance—which is one of the most troublesome things to treat. Take a magnet, about 3 inches long and ¼ inch square. It will be found that polarity is situated principally in the neighbourhood of the arms, and these are the points to be first attacked. Hang the balance by its rim on a piece of brass wire, and approach the magnet towards the rim in the direction of one of the bars. If it should be attracted towards the magnet, try the other pole, and it will be found to repel. Now take the balance in your hand and bring the *repelling* pole of the magnet in momentary contact with the balance at the point tried, then test it with a minute fragment of small iron binding wire; if still magnetic, bring the magnet in contact again, and so on—trying after each contact—till the magnetism is entirely out at that point. Suspend the balance on the brass wire, as before, and proceed to try the rim at the point where the second arm comes, and the same with the third. Having got the magnetism out at these three points, there will be but little remaining in the balance. However, try it carefully all round, when several places will probably be found retaining sufficient magnetism to pick up a small fragment of iron. These must all be treated in the manner before described; but when the magnetism is very feeble, a smaller magnet must be used, for if the magnet is too powerful, the article operated upon discharges what little remains, and, before contact can be broken, begins to pick up again of the reverse pole. After having operated successfully on the other portions of the balance, it frequently happens that it has become slightly charged again by one of the arms; try the pole as before, and a few contacts, sometimes but one, of one of the smaller magnets will suffice. A little patience is required, for it is often twenty minutes or more before the desired end is accomplished. After treating a balance always try whether it is in poise. The pendulum stud, which is usually found to be charged when the balance is so, is easily treated. Try the poles, and a few contacts will draw all the magnetism out of one end, when so little will be found remaining in the other, that one touch of the other pole will usually be sufficient. Even the balance spring may be successfully treated, though so strongly charged as to be "feathered" with iron filings after being immersed in them. A good way to try the polarity of many pieces is to suspend the article, by means of a particle of wax, to a piece of the finest silk. Steel filings, or fragments of chain wire, should on no account be used for testing; for if not magnetic to begin with, they speedily become so by contact with the article under treatment. Even with soft iron, it is well to change the fragment you are testing with occasionally.

Mending Marble Clock Cases.—Plaster of Paris may be used, bnt it is better, especially if the mended part is visible, to soak the plaster of Paris in a saturated solution of alum, and then bake it. It is used with water, may be mixed with any desired colouring material, and will take a high polish.

Friction.—Friction is defined as the resistance experienced when one hard body is rubbed upon another, caused by the tendency of the asperities which exist on all surfaces, however highly polished, to interlock, together with the natural attraction which bodies have for each other, and possibly some electric action. The force necessary to overcome friction varies directly as the weight or pressure with which the bodies are kept in contact, and is independent of the amount of surface over which the weight or pressure is spread. If the surfaces are too small in proportion to the pressure, they will be rapidly worn away; and if the disproportion be very great, one or both of the surfaces will be destroyed by abrasion. With most substances used for the acting surfaces of machines this abrading action would very quickly develop itself were the surfaces allowed to come into absolute contact, therefore a film of some lubricant is interposed, which of itself has a retarding influence; but in machines of any size or weight the amount is very small, compared with the friction proper—the attrition of the metallic surfaces. The viscidity of the unguent employed is also proportioned to some extent to the weight; but it is possible to have the weight so small that, even with the most fluid unguent, the adhesion of the unguent is far greater in amount than the attrition of the metallic surfaces. In the balance-staff pivots of a watch, for instance, there can hardly be said to be friction at all, nearly the whole of the resistance arises from the adhesion of the oil, the amount of which is exactly proportionate to the extent of the surfaces in contact, instead of to the weight; and as the fluidity of the oil cannot be kept constant, owing to the action of the metallic surfaces and the atmosphere, the varying sum of the resistance is a source of great perplexity to watchmakers. The surfaces in contact are therefore wisely made very small in cases where the greater part of the resistance arises from the adhesion of the oil. Towards the barrel where the pressure is greater larger surfaces are desirable, and a thicker oil should be used. When very thin oil, which is proper for the escapement, is used to the centre and fusee pivots one often hears of complaints of these pivots becoming dry and cutting. In clocks the barrel and train pivot holes are often improperly reduced to nearly the same lengths as the verge and escape holes. Where extra surface is desired for the bearings of arbors, &c., it should be obtained by increasing the length and not the diameter, for if the *diameter* of a pivot or bearing of any kind is doubled the resistance to motion is doubled also because the revolving surface is then twice the distance from the centre of motion.

To Refine Sweepings containing Gold or Silver.—To 8oz. of the dirt, which has been washed and burnt, add 3ozs borax, 2 to 3ozs. of saltpetre; give a good heat, then add a piece of salt; the gold will turn out quite clean.

Silver Solution for Electro-Silvering.—Dissolve ½-ounce of silver in nitric acid, dilute and precipitate, wash and place it in a china vessel, and pour a solution of 5 ounces of yellow prussiate of potash in about a pint of water, and add to it about 2 ounces of spirits of ammonia; boil the whole for about an hour, and keep adding as much water as may have evaporated; let cool and filter, when it will be ready for use. It should be kept in stoppered bottles. This solution will be found useful in matching the gilding in parts of watches. It should be mixed with the gold solution till the right colour is obtained.

Comparison and Birmingham Wire Guage with Inches.—

B.W.G.	*Inches.*	*B.W.G.*	*Inches.*	*B.W.G.*	*Inches.*	*B.W.G.*	*Inches.*
1	·3	10	·134	19	·042	28	·014
2	·284	11	·12	20	·035	29	·013
3	·259	12	·109	21	·032	30	·012
4	·238	13	·045	22	·028	31	·01
5	·22	14	·083	23	·025	32	·009
6	·203	15	·072	24	·022	33	·008
7	·18	16	·065	25	·02	34	·009
8	·165	17	·058	26	·018	35	·005
9	·148	18	·049	27	·016	36	·004

Gilding Parts of Watch Movements (Martens).—After being well stoned and cleaned the parts to be gilded are brushed with carbonate of soda and water and then dipped in a solution of

25 parts oil of vitriol (commercial)
25 ,, nitric acid ,, and
3 ,, common salt.

Care should be taken in dipping small or thin articles as the acid weakens them. After they have a clean and even surface, the articles are silvered.

Put into a porcelain basin

24 parts of common salt
6 ,, cream of tartar
1 ,, silvering powder (described below).

Add rain or distilled water to make a thin cream and mix well. The articles are then fastened with pins to a flat piece of cork and gently brushed with the mixture. The brush should be short-haired and stiff and be soaked previously in salt water to remove grease and to soften it. Take care not to apply too much of the mixture to begin with, as by doing so an unequal coat of silver would be deposited, which may cause a part to peel off. The articles are then removed from the cork are brushed with carbonate of soda and water, and well rinsed, after which they are scratch-brushed in soap-water, until the frosting becomes bright. The scratch-brush to be used for this purpose ought to be annealed on a charcoal fire before using it, to enable the operator to bend the ends of the brush, after being cut open, in a straight way. The open end should occasionally be rubbed on a nutmeg-grater, and then cut even with a pair of scissors. After silver frosting, the articles are well rinsed in rain or distilled water, and are ready to receive the gilding.

The apparatus for gilding consists of a glass jar, 4 inches in diameter and 8 inches deep. An amalgamated* zinc plate about ·2 inches thick is bent to the shape of an open cylinder small enough to go into the glass jar. An upright copper wire is soldered to the top of the zinc plate so as to rise above the glass cylinder about 7 inches ; it is then bent over at right angles to form a rail from which to hang the articles to be gilt. An open glass cylinder 2·5 inches diameter and 3 inches long is, by means of wire claws, rested on the larger glass jar so that about half of its height is below the top of the jar. The lower end of the glass cylinder which has a small rim

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* The amalgamation of the zinc plate is attained by immersing it in diluted sulphuric acid, and then brushing mercury all over evenly with a cloth.

is closed by means of a piece of bladder, softened by soaking, tied tightly round the rim. In this cylinder the gold solution (which is described at the end) is poured, and the glass jar holding the zinc cylinder, is filled with a saturated solution of common salt of about the same density as the gold solution. This prevents pressure on the bottom of the upper cylinder. The parts to be gilded are then suspended on thin copper wires on the rail into the gold solution, so that they are fully immersed. The immersed articles soon assume a yellow colour, and after they have been kept in the solution fifteen or twenty minutes, remove them and scratch-brush with the soap solution until they appear bright. They are then well rinsed and again suspended for fifteen or twenty minutes in the gold solution, when they will have a sufficient coating of gold. If the solution is new two immersions are quite sufficient to obtain the desired thickness of gilding. After this, it is requisite to scratch-brush the gilt articles in soap water with a very fine and soft scratch-brush, gently applied until the gilding is assuming an all-over equally bright surface. The gilded articles are dipped in clean water, and then in spirits of wine, and dried in fine sawdust. Should small scratches appear on the gilt articles they must be again immersed in the gold bath and be rescratch-brushed. These scratches are caused by careless scratch-brushing and it is necessary to bestow attention to this part of the operation to obtain a faultless frosted gilding.

Varnish for Pinions.—In gilding wheels fastened to pinions the pinion must be varnished—

5 parts resin
2 ,, yellow beeswax
2 ,, oxide of iron

The first two are melted together and the oxide then added. After stirring it is poured into a convenient vessel. Heat a small spoon sufficiently to pierce the varnish after it has set. The heat will melt the varnish taken up into the spoon and the pinion should be dipped into it. Take care it is wholly covered and that none of the varnish is on the wheel.

Silver Powder for Frosting.—Dissolve sterling silver in as little nitric acid as possible. Dilute the solution with an equal quantity of rain-water, to which saturated salt water is added as long as a white precipitate will form. The precipitate is allowed to settle, and a single drop of the rain-water thrown in. If the solution is disturbed, more salt water is added. The water is poured off, and the precipitated silver washed several times in lukewarm rain-water to clear it from acid, and spread out on white paper, dried on the stove, and bottled for future use.

Gold Solution.—One pennyweight of fine gold rolled very thin and cut into small pieces is dissolved in *aqua regia* (two parts of muriatic to one part of nitric acid), evaporated to dryness, and then washed into a small quantity of rain-water and filtered. Dissolve five pennyweights of yellow prussiate of potash and three pennyweights of carbonate of soda in about a pint of rain or distilled water, and boil this solution in an enamelled saucepan, or in a china vessel immersed in an outer vessel of iron or tin containing boiling water, and add the gold solution to this, when the whole will assume a darkish colour, and leave a brown precipitate, which will soon settle to the bottom if the whole is kept boiling. As soon as the precipitate is settled, the solution is removed from the fire, left to cool, and filtered. The gold solution is then ready, and can be poured into well stoppered bottles for preservation, and will improve by keeping.

To Cut Zinc.—Make a deep scratch at the place of desired separation, repeat this on the opposite side, and run mercury into the cut. This will soak through in a few minutes, and the plate may be divided by bending over the edge on a table.

Dissolving Soft Solder.—Nitric acid is the quickest solvent and may be used safely for not lower than 12 carat gold. The safest solvent suitable for all grades of gold and silver goods, which is recommended by Mr. George E. Gee, is prepared as follows:—Reduce to a fine powder 2oz. of green copperas and 1oz. of saltpetre, add 10oz. of water, and boil for some time in a cast iron saucepan. On cooling it will become crystallized either wholly or partially. Pour off any remaining uncrystallized and boil it again, when it also will crystalize in cooling. Dissolve the crystals by placing them in a pipkin and adding to 1 part of crystals 8 parts of spirits of salts. Pour on 4 parts of boiling water, keep the mixture hot, and immerse the work to be operated upon. In a short time the whole of the solder will be removed without changing the colour of the work.

Gold Soldering.—The article to be soldered is placed upon a bunch of old binding wire, hammered flat. If a breach or crack has to be filled a small thin plate of the same quality of gold as the article under repair should be used. Borax *one side* of the plate and run small pallions of suitable solder evenly over it. The plate is then boiled in diluted sulphuric acid, and hammered or rolled very thin. A bit of this gold plate of a shape to fill the breach is cut off. Any old solderings near the breach should be coated with a paste of red stuff mixed with water, and to preserve the polish and colour of the article it should be covered with equal parts of borax and charcoal pounded up together and mixed into a paste with water. This "black stuff," which must be carefully excluded from the part to be soldered, is dried. Any stones or settings in the article should be covered with a thick paste of whiting and water; or some bury the part in a piece of raw potato. If it is a ring that is being soldered on the opposite side to the settings, a piece of charcoal may also with advantage be placed through the ring. When all necessary precautions have been taken, the breach is boraxed and the piece ot plate laid in, and heat directed to it by means of a blow pipe. Care must be taken not to apply too much heat. When the solder begins to flow the plate will drop slightly, and the solder round the edges of it glisten. By following this method a strong job is made, the colour of the article preserved, and very little cleaning is required afterwards.

Great care is needed in dealing with very low quality gold rings when broken. File the edges flat, so that no light is seen through when brought together. Cut a VERY thin piece of silver solder, a trifle larger than the section of the ends. Cover the ends with borax, and place the piece of silver solder between them. Apply heat with the blow pipe till the solder begins to glisten.

Gold Solder.—For 18 carat gold—18 carat gold, 12 parts; fine silver, 2 parts, brass wire, 1 part. For lower qualities of gold substitute for the 18 carat gold the same standard as the article to be soldered, and add the same proportion of silver and brass wire as given above. For the brass wire pins are generally used, as they contain a little tin, which is an excellent ingredient for causing the solder to flow. Some jewellers use copper instead of the brass pins and add a little zinc. Ordinary silver solder is quite unsuitable for gold work, which has to be coloured.

Silver Solder.—To 1 oz. of standard silver add 6½ dwt. of white pins; melt the silver first with a good piece of borax.

Jewellers' Solder.—Fine silver, 19 parts; copper, 1 part; brass pins, 10 parts.

White Silver Solder.—Equal parts of silver and tin; melt the silver first.

Soft Solder.—Pure tin 2 parts, pure lead 1 part; melt the lead first.

Solder for Pewter and Britannia Metal.—Tin 10 parts, lead 5 parts, Bismuth 1 to 3 parts according to the work; melt the lead first.

Soldering Fluxes.—With hard solder use borax; with soft solder chloride of zinc prepared by dissolving small pieces of zinc in spirits of salts till no more can be dissolved.

Jewellers' Cement.—Dissolve gum mastic in spirits of wine. Soften an equal weight of isinglass in water. Dry it, and dissolve it separately in spirits of wine. Rub in with it till dissolved half the weight of gum ammoniacum. Add the dissolved gum mastic, and heat till thoroughly mixed. Keep tightly corked, and set the bottle in boiling water before use.

Restoring Silver Jewellery.—Silver ornaments which have merely become oxidized by exposure in a sulphurous atmosphere, and not by repeatedly cleaning, are simply restored by brushing with a clean brush and a little carbonate of soda. To restore the original dead or lustrous whiteness of silver goods, lost by having been too often and carelessly cleaned they should be, if not soft soldered or very fragile, first annealed by being held in a pair of pincers close over the flame of a lamp till covered with soot, which is then burnt off by means of a blow pipe. Then the articles should be immersed in a hot solution, of from one to five parts of sulphuric acid and twenty parts of water—the quantity of acid depends on the quality of the silver the articles are made of, the coarser the silver the more acidulated. The time for the articles to remain in the solution also depends on the quality of the silver, whilst good sterling silver will be whitened in almost an instant, commoner silver will take a minute, or even longer; care is, however, to be taken not to allow the articles to remain too long in the solution, which would turn the surface into an unsightly greyish colour, and the manipulation will have to be commenced afresh. As soon as the desired whiteness of the articles whilst in the acid is observed, they are removed and quickly thrown into lukewarm water; it is advisable to have an additional vessel with warm water at hand, to place the articles in after having been removed from the first. The articles are then immersed in boxwood sawdust, kept in an iron vessel near the stove, or any warm place, when, after thoroughly drying in the sawdust, the articles will be found to look like new. Any places on the articles desired to look bright, are burnished with a steel burnisher. If the articles are soft soldered or very fragile the first process of annealing must be dispensed with.

Artificial Gold.—Take 100 parts (by weight) of pure copper, 14 parts zinc or tin, 6 parts magnesia, 3·6 parts sal-ammoniac, 1·8 parts quick-lime, 9 parts cream of tartar. Melt the copper, and add gradually the magnesia, sal-ammoniac, quicklime, and cream of tartar, each by itself, in the form of powder. Stir the whole for half an hour, add the zinc or tin in small pieces, and stir again till the whole is melted. Cover the crucible, and keep the mixture in a molten condition for thirty-five minutes. Remove the dross, and pour the metal into moulds. It has a fine grain, is malleable, and does not easily tarnish.

Drilling Glass.—Turpentine is generally used with the drill, but diluted sulphuric acid is much better.

Cementing Metal to Glass.—Mix two parts of finely powdered litharge and one part of fine white lead; mix three parts of boiled linseed oil with one part of copal varnish; stir the powder into the liquid until it has the consistency of a stiff dough. Spread the cement on the metal, press it against the glass, and scrape off the surplus. It dries quickly and is remarkably tenacious.

Varnish for Brass.—Yellow brass may be made to keep its colour without appearing varnished by means of a thin varnish of white shellac or a coating of collodion.

Lacquering Brass.—The articles must be boiled in a strong solution of equal parts of pearlash and slaked lime, to thoroughly remove all old lacquer and greasy matter; then rinsed in water and scoured with sand, or scratch-brushed, rinsed again and dried. They are then immersed for a moment in a dipping solution, consisting of one part of sulphuric acid, one part of nitric acid, two parts of water, and a very little hydrochloric acid, and withdrawn to be dipped in two clean waters. If the colour is not uniform the dipping and rinsing is repeated. The articles are then dried in warm sawdust, and rubbed with a clean cotton cloth to remove any stain of finger marks from handling. They are placed on a stove or heated iron plate until warm enough to hold in the hand; the lacquer fs then applied evenly by means of a piece of soft-sponge and the articles set aside in a dust-free place to dry.

To Preserve Pearls.—Pearls will never tarnish and lose their brilliancy if kept in dry, common magnesia, in lieu of the cotton wool used in jewel cases.

To Oxydise Silver.—Dissolve one ounce sulphuret of ammonia in one pint of hot water. Dip the articles for a few seconds; lay them in water; scratch-brush well; rinse.

To Oxydise Gold, Silver, Brass, or other Metal.—Paint over the parts to be oxydised with a solution of chloride of platinum, then let it dry. To make the cloride of platinum in solution, dissolve one drachm in two ounces of hot water.

To Frost Watch-Caps, Plates, &c.—2½ nitric acid, 2 muriatic acid, full strength. Dip the articles for a few seconds; rinse in water; scratch-brush with a circular motion; then gild.

Whitworth's Proportions for Screws.—The angle of thread = 55°; depth of thread = pitch of screw; ⅙ of the depth is rounded off top and bottom.

The first table gives the ordinary engineers' threads. The second is the threads specially arranged by Sir Joseph Whitworth for watch and small instrument makers:—

Size of Screw in inches.	*No. of Threads per inch.*	*Size of Screw in inches.*	*No. of Threads per inch*	*Size of Screw in inches.*	*No. of Threads per inch.*
·1	48	·25	20	·4	16
·125	40	·275	20	·425	14
·15	32	·3	18	·45	14
·175	24	·325	18	·475	14
·2	24	·35	18	·5	12
·225	24	·375	16		
·010	250	·022	180	·050	100
·011	,,	·024	,,	·055	,,
·012	,,	·026	150	·060	80
·013	,,	·028	,,	·065	,,
·014	,,	·030	,,	·070	,,
·015	210	·032	120	·075	,,
·016	,,	·034	,,	·080	60
·017	,,	·036	,,	·085	,,
·018	,,	·038	,,	·090	,,
·019	,,	·040	100	·095	,,
·020	180	·045	,,	·100	50

Comparison of English and French Measures.

Millimètres	1	2	3	4	5	6	7	8	9	10
Inches	·0393	·0787	·1181	·1574	·1968	·2362	·2756	·3149	·3543	·3937

NOTE.—10 Millimetres = 1 Centimetre; 10 Centimetres = 1 Decimetre. A millimetre equals the $\frac{1}{25}$ of an inch nearly.

Tempering Steel.

Colour.	Purpose.	Temperature.	Alloy, whose fusing point is of the same temperature.	Effect on Tallow.
Pale straw -	Lancets and Tools for Cutting Iron - - - - - -	420° Fah.	7 lead 4 tin	Vapourises.
Straw - -	Watchmakers' Tools - -	450° ,,	8 ,, 4 ,,	Smokes.
Straw yellow -	Pen Knives and Razors - -	480° ,,	8½ ,, 4 ,,	More smoke.
Nut brown -	Small Pinions and Arbors -	500° ,,	14 ,, 4 ,,	Dense smoke.
Purple - -	Large Pinions and Arbors -	530° ,,	19 ,, 4 ,,	Black smoke.
Bright blue -	Swords and Watch Springs -	580° ,,	48 ,, 4 ,,	Flashes if light is applied.
Deep blue -	Watch Balance Springs - -	590° ,,	50 ,, 2 ,,	Continuous burning.
Blackish blue	Chronometer Balance Springs	640° ,,	All lead or boiling linseed oil.	All burns away.

NOTE.—Steel is both harder and tougher if hardened in oil instead of water. Steel is less oxidized by tempering in an alloy than if tempered in the air, and the required temperature is obtained with much greater certainty.

Thermometers.—Comparison of the scales of Fahrenheit, Réaumur and the Centigrade, between the freezing and the boiling point of water:—

Fahr.	*Raum.*	*Cent.*	*Fahr.*	*Raum*	*Cent.*	*Fahr.*	*Raum.*	*Cent.*
212	80	100	110	34.7	43.3	68	16.0	20.0
203	72	96	107	33.3	41.7	65	14.7	18.3
194	76	90	104	32.0	40.0	62	13.3	16.7
185	68	85	101	30.7	38.3	59	12.0	15.0
176	64	80	98	29.3	36.7	56	10.7	13.3
167	60	75	95	28.0	35.0	53	9.3	11.7
158	56	70	92	26.7	33.3	50	8.0	10.0
149	52	65	89	25.3	31.7	47	6.7	8.3
140	48	60	86	24.0	30.0	44	5.3	6.7
131	44	55	83	22.7	28.3	41	4.0	5.0
122	40	50	80	21.3	26.7	31	2.7	3.3
119	38·7	48·3	77	20.0	25.0	35	1.3	1.7
116	37·3	56·7	74	18.7	23.3	32	0.0	0.0
113	36·0	45·0	71	17.3	21.7			

NOTE.—Zero Fahrenheit corresponds with *minus* 17·78 Centigrade, and *minus* 14·22 Réaumur. Any other number of degrees, Centigrade or Réaumur, may be converted into degrees Fahrenheit by the following rules:—

Let F. = No. of Degrees Fahrenheit.
,, C. = ,, ,, Centigrade.
,, R. = ,, ,, Réaumur.

$$\text{Then } F = \frac{C \times 9}{5} \times 32 \text{ or } F = \frac{R \times 9}{4} \times 32$$

Sizes of Wycherley's Watch Movements.

Size.	*Diameter in Inches.*	*Size.*	*Diameter in Inches*
No. 4	1·34	No. 12	1·62
No. 6	1·41	No. 14	1·69
No. 8	1·48	No. 16	1·76
No. 10	1·55	No. 18	1·83

Usual Lancashire Sizes.

No.	*Inches.*	*No.*	*Inches.*	*No*	*Inches.*	*No.*	*Inches.*	*No.*	*Inches*
1	1·2	6	1·366	11	1·533	16	1·7	21	1·866
2	1·233	7	1·4	12	1·566	17	1·733	22	1·9
3	1·266	8	1·433	13	1·6	18	1·766	23	1·933
4	1·3	9	1·466	14	1·633	19	1·8	24	1·966
5	1·333	10	1·5	15	1·666	20	1·833	25	2·0

Watch Balances.—Sizes of Plain Balances generally used for Full Plate Watches :—

No. of Watch movement—	4	6	8	10	12	14	16	18
Size of Balance in inches—	·58	·61	·64	·68	·71	·74	·77	·8

Sizes of Plain Balances generally used for ¾ plate Watches :—

No. of Watch movement—	2	4	6	8	10	12	14	16	18
Size of Balance in inches—	·47	54	·53	·56	·59	·62	66	·69	·72

The rough rule for a full-plate watch is that the diameter of the balance should be half that of the top plate ; for a three-quarter-plate watch that the balance should be the size of the outside of the barrel if a 16,200 train, and of the inside of the barrel if for an 18,000 train.

To Polish Mother of Pearl, Ivory, and Horn.—Rub with wet linen cloth dipped in finely powdered pumice-stone, finish off with putty powder and a wet rubber. Ivory which has become discoloured may be restored by exposure to the sun's rays *under glass.* If not placed under glass the surface will crack.

To Mend Amber.—Smear the surfaces to be united with linseed oil, and wrap the rest of the article loosely in paper. Hold the oiled parts one on each side of a small bar of hot iron—not too close—till they are just sticky, when press them together and hold them till well set.—Or a very good cement without heat may be made of quicklime mixed to a thick cream with white of egg.

Black for Brass or Zinc Work.—Mix lampblack on a stone with gold size. If a dull black is desired make it to a very stiff paste ; if a more polished surface, then use more gold size. Add turpentine to thin it, and apply with a camel-hair brush.

To Keep Steel Articles from Rusting.—Cover them with powdered quick-lime. If they must be exposed place near them a small open vessel containing chloride of calcium. Immerse rusted steel articles for a few minutes in a strong solution of cyanide of potassium, and they will clean much easier.

Colour, Degree of Hardness, Specific Gravity, and the kind of Refraction (Single or Double) of the Principal Gems:—

	Colorless.	*Red*	*Yellow.*	*Green.*	*Blue.*	*Violet.*	*Brown*	*Blue.*	*Hardness.*	*Specific Gravity.*	*Refraction.*
Diamond	*		*	*	*		*	*	10	3.5	S
Sapphire	*	*	*	*	*	*			9	3.9—4	D
Chrysoberyl			*	*					8.5	3.8	D
Spinel		*		*	*	*			8	3.7	S
Topaz	*		*	*	*				8	3.5	D
Zircon	*	*	*	*			*		7.5	4.6	D
Beryl	*		*	*					7.5	2.7	D
Emerald				*	*				7.5	2.6	D
Rock Crystal	*		*				*		7	2.7	D
Amethyst						*			7	2.7	D
Chrysolite				*					6—7	3.4	D
Garnet		*		*		*	*	*	6—7	3.8	S
Tourmaline		*		*	*	*	*	*	6—5	3.1	D
Turquoise				*	*				6	2.6—3	
Lapis Lazuli					*				5.5	2.4	
Opal	*	*	*	*					6	2.3	

NOTE.—To ascertain the specific gravity of gems in the absence of a proper hydrostatic balance place a small glass partly filled with distilled water in one pan of a pair of sensitive scales. Attach a horse hair with a loop to the scale beam over the water and add weights to the other pan to produce equilibrum. Tie the stone to the horse hair and note its exact weight in the air. Then lower the horse hair so that the stone is immersed in the water and again note its weight. Divide the weight in air by the difference between the weight in air and the weight in water and the quotient will be he specific gravity.

A Carat, universally used as a weight for diamonds, contains four grains.

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